

STOMATA NUMBER AND INTERRELATIONSHIPS AMONG AGRONOMIC  
TRAITS IN F<sub>1</sub> HYBRIDS OF GRAIN SORGHUM,  
SORGHUM BICOLOR (L.) Moench

by

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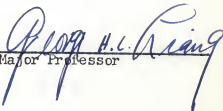
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TABLE OF CONTENTS

INTRODUCTION . . . . .	1
REVIEW OF LITERATURE . . . . .	2
Stomata . . . . .	2
Interrelationships Among Agronomic Characters . . . . .	4
MATERIALS AND METHODS . . . . .	8
Field Experiments . . . . .	8
Statistical Analysis . . . . .	12
RESULTS AND DISCUSSION . . . . .	14
Stomatal Numbers and Yield . . . . .	14
Multiple Linear Regression . . . . .	17
Standard Partial Regression . . . . .	17
Interactions of Kernel Number, Kernel Weight, and Head Number . . . . .	20
Interrelationships Among Traits . . . . .	22
SUMMARY AND CONCLUSIONS . . . . .	31
ACKNOWLEDGMENTS . . . . .	36
LITERATURE CITED . . . . .	33
APPENDIX . . . . .	37

## INTRODUCTION

The development of high yielding populations of grain sorghum, superior to those now available, is an important goal in grain sorghum breeding. However, yield and most other traits that breeders are interested in are not simply inherited in a Mendelian fashion. Therefore, progress in breeding programs may be considered as a function of interrelationships of genetic and nongenetic variations in those important traits.

Major yield components of grain sorghum are kernel number and kernel weight. Little progress has been made in the exploration and explanation of the associations among these complexly inherited traits and other important agronomic traits.

A knowledge of the interrelationships among agronomic traits is of value because it provides a basis for the development of selection indexes for the simultaneous improvement of traits, for avoiding selection of undesirable traits, and for efficient selection of traits with low heritabilities. Since grain yield has a low heritability in grain sorghum, it is of great value to know the traits which are highly associated with it to maintain a highly effective breeding program for high grain yielding capacity.

The purposes of this investigation were (1) To find if there is a correlation between stomatal number and yield, with detailed analysis and interpretation, (2) To find the relative importance of contributing factors toward yield by multiple regression analysis, (3) To estimate the interrelationships between kernel weight and kernel number per plant under 2 different plant spacings, specifically 6 and 12 inches within rows, and (4) To determine interrelationships between pairs of variables observed under 2 different plant spacings.

## REVIEW OF LITERATURE

STOMATA

There is considerable diversity in stomatal density between species in regard to the variability within and between the leaves. Eckerson (1908) reported that in most leaves studied the stomata were fairly evenly distributed over the surface of the blade, but in some species the stomata were more numerous near the midrib than near the margin of the leaf. Peterson (1929) reported that in varieties of Rumex acetosa from different habitats that stomatal frequency varied little between the regions of the same lamina. Wicks (1935) found that in Amaryllidaceus, stomatal frequency increased from the base of the blade toward the apex and from the median line to the margin of the lamina. Yapp (1912) and Cowart (1936) reported that stomatal frequency was greater in the higher leaves of apple trees than in the lower leaves. Yapp (1912) also stated that transpiration rate through the smaller but more numerous stomata of the upper leaves was not much greater than that through the larger but fewer stomata of the lower leaves of Ulmaria palustris.

Smith (1941), using Phaseolus vulgaris, found that stomatal frequency within a leaf was the highest near the apex and the lowest near the midrib, and in different leaves it was apparently higher at the upper than at the lower levels of a plant. Smith also stated that there was a positive correlation between stomatal frequency and transpiration rate.

Hesketh (1963), working with castor beans (Ricinus communis), maize (Zea mays), tobacco (Nicotiana tabacum), red clover (Trifolium pratense), sugarcane (Saccharum officinarum), and sunflower (Helianthus annuus), reported that stomatal frequency and length were not related to maximum photosynthesis.

Freeland (1948) also found that stomatal frequency was not correlated with greater photosynthesis among the same species of several plants.

Roovaart and Fuller (1935) working with cereals explained the variation of stomatal frequency within a species was due to optimum conditions or below optimum conditions. A low frequency under optimum conditions is found because the epidermal cells are larger and hence there is greater distance between the stomata. Evidently, it follows that, the ratio of the number of stomata to that of epidermal cells remains about constant under all conditions.

Hunt and Christie (1969) working with leaves of brome grass, found there were variations in stomatal numbers and lengths between plants of the same varieties. Those differences could also be detected with some degree of reliability by using a silicon impression technique.

Miller (1938) classified a large number of species and varieties of crop plants on the basis of stomatal characteristics and concluded that the number of stomata per unit area of leaf surface is within limits, specific for different varieties and species.

Dunn (1965) reported that the size of stomata in monocotyledons was much more consistent than in dicotyledons. However, he concluded that the frequency per unit area was a more reliable characteristic in both monocotyledons and dicotyledons with size of stomata being a fairly reliable characteristic in monocotyledons.

Birdsall and Neatby (1944) working with Triticum vulgare and other Triticum spp reported that there were significant differences among varieties and hybrid strains of spring wheat with respect to the length and frequency of stomata per unit area. A negative correlation was found between size and frequency of stomata both between species and between varieties within a species.

Yield was found to be significantly correlated with stomatal frequency, while the relation with stomatal size was negative. Differences in plants were found to have a bearing on stomatal characteristics among varieties, small plants had small stomata and relatively large number per unit area, larger plants had larger stomata and fewer per unit area.

Eckerson (1908) and Muenscher (1915) demonstrated that there is an inverse relationship between frequency and size of stomata. Dobrenz, Wright, Humphrey, Massingale, and Kneebone (1969) working with Blue Panicgrass (Panicum antidotale Retz), reported that leaves adjacent to the inflorescence had significantly lower stomatal density than those at the middle and base of the culm. No difference was found among stomatal densities at the three positions on a leaf; tip, middle, and base. A nonsignificant correlation between water-use efficiency and stomatal density was also reported.

Teare (1969), from research with wheat (Triticum vulgare) found that stomates varied from 9,000 to 16,000 stomates per  $\text{cm}^2$  for flag leaves between varieties and species. Differences were also found between leaves on the same plant. On the average it was found that on the flag leaf there was an average of 12,200 stomates/ $\text{cm}^2$  compared with 10,300 stomates/ $\text{cm}^2$  on the first leaf below the flag leaf. The second and third leaves are similar to the first leaf. Originally the tip, mid section, and base of the leaf were sampled, however, the mid section proved to be the most reliable.

#### INTERRELATIONSHIPS AMONG AGRONOMIC CHARACTERS

Interrelations among agronomic characters in grain sorghum (Sorghum bicolor Moench) has been investigated by several authors. Of the primary components of yield in grain sorghum, weight of seeds, number of seeds per

head, and number of heads per unit areas, it was concluded that seeds per head was the most important (Nielaus 1966, Quinby 1963). Kirby and Atkins (1968) studied the inter-character correlations among 24  $F_1$  grain sorghum hybrids and found grain yield was positively and significantly correlated only with seeds per head. Dalton (1967) after testing  $F_1$  hybrids with a wide range of maturities concluded that a positive regression existed between higher yields and later maturity.

Liang (1969) estimated phenotypic and genotypic correlations among characters for 15  $F_1$  hybrids (Sorghum vulgare Pers) and found that grain yield was positively and significantly correlated with half bloom date but the correlation with kernel weight was low. Liang, Overley, and Casady (1965) in a later investigation with pure lines and segregating populations of grain sorghum (Sorghum bicolor Moench), found that grain yield was positively and significantly correlated with head weight, kernel number, half bloom date, and leaf number. An inverse relationship between kernel weight and kernel number was also found in this study. Head weight and half bloom date were considered the best indicators for yield.

Niehaus and Pickett (1966) using 28  $F_1$  hybrids of grain sorghum (Sorghum vulgare Pers) determined that grain yield was positively and highly significantly correlated with seeds per head, plant height, half bloom date, number of leaves, and threshing percentage. In the  $F_1$  generation number of seeds per head had the largest direct effect on yield. Although height was highly correlated with yield, its influence was indirect and was primarily through number of seeds per head.

Rao et al. (1965) emphasized the importance of the study of the association of yield components with yield since the component characters which have

decisive roles in influencing yield may be used for additional indices for selection from breeding material. They listed 6 characters as the grain sorghum yield components, 1) number of tillers per plant, 2) length of panicle, 3) weight of ear-head, 4) days to maturity, 5) threshing percentage, and 6) test weight. In the study of correlations between the yield components and the final yield, they reported that weight of ear-head, days to maturity, and test weight were highly and significantly correlated. But lengths of panicle were negatively correlated. Number of tillers and threshing percentage were not significantly correlated.

Sieglinger (1936) using different varieties of grain sorghum (Sorghum bicolor Moench) reported that numbers of leaves was positively and significantly correlated with half bloom date, diameter of stalk, and plant height. Casady, Hadley, Freeman, and Javier (1965) found that plant height was positively and significantly correlated with grain yield.

Blum (1967) found that with higher soil fertility the 1000 grain weight tends to increase along with the number of branches per whorl, and the number of grains per branch. Low plant competition, rows 30 inches wide, increased the number of whorls per panicle and the number of grains per branch, compared with high plant competition or rows 50 inches wide. These factors contributed to a significant increase in the number and weight of grains per panicle. There was a negative correlation, which increased as the number of grains per panicle increased, between the weight of grain and number of grains per branch. Martin (1928) reported that within a given variety of grain sorghum (Sorghum vulgare Pers), that height of plant is highly correlated with grain yield and that conditions which favor elongation of the internodes of the sorghum stalk also favor an increase in the number and size of seeds per head.

Thus, environmental conditions favorable for greater plant height also favored greater yields per acre and greater seed size.

Atkins, Reich, Beil, and Kirby (1968) found an association between panicle weight and threshed grain weight in grain sorghum. However, they concluded that for most studies the separation of the grain from the panicle was a necessary procedure for accurate yield estimations.

Adams (1967), using field beans (Phaseolus vulgaris), found that negative correlations among yield components are widespread among the major crop plants, particularly under various kinds of environmental stress and these correlations are attributable to developmental induced relationships rather than genetically inherited.

## MATERIALS AND METHODS

### FIELD EXPERIMENTS

Thirty-six  $F_1$  hybrid lines of grain sorghum were planted in fall-plowed, weed-free seedbeds in 1969 and 1970. They were: WAC 690-A; T.E. Mucho; Weather Master 76-Y; RS 702; RS 633; RS 626; RS 625; Richardson 404 SR; P.U. 685; Pioneer 820; Pioneer 845; P.U. 634; Pioneer 846; Pioneer 828; NK 222A; Excel 707; Frontier 413; Excel 505; NK 222G; Dekalb F-64; NC-T-700; Asgrow Flare; NK 275; Horizon 80; Dekalb E-57; Asgrow Jumbo C; Dekalb C-48a; Advance 91; Dekalb C-44c; Advance 76; Acco R2020; Acco R109; Weather Master G-61y; and T.E. Grain Master A.

Two locations were used in each of the 2 years. Kansas State University Agronomy Farm at Manhattan (1969) and Ashland (1970), and the Experiment Field at Powhattan, Kansas (1969 and 1970). The  $F_1$  hybrids of grain sorghum were planted in rows spaced 91 cm (36 inches) apart in both experiments in 1969 and Powhattan in 1970, but in 1970 at Ashland the row spacing was 76 cm (30 inches). The plants within the rows were thinned to 15 cm (6 inches) apart in the first experiment and thinned to 30 cm (12 inches) apart in the second experiment. This same row spacing and plant spacing were used in both years at both locations. A cone type hand planter was used to do all of the planting in 1969, and all but 7 hybrids in 1970, where the amount of seeds was limiting and hand planting was necessary.

Grain sorghum hybrids at Manhattan were planted on June 16, 1969 for the first experiment and on June 25, 1969 for the second experiment. Those plots were planted in a alluvial silty clay loam soil, with a previous crop of wheat. In 1970, the grain sorghum at Ashland was planted on June 17 for the

first experiment and on June 18 for the second experiment on very similar soil types with soybeans as the previous crop.

Soil moisture condition at planting time was good at both Manhattan and Ashland in 1969 and 1970, respectively. Precipitation for the first 60 days after planting at Manhattan in 1969 totaled almost 12 inches. While at Ashland in 1970 the precipitation for the first 60 days after planting totaled only 3 inches. The rain was fairly well distributed in 1969, but in 1970 rain was negligible the first 8 weeks after planting. High temperatures accompanied by hot, dry winds put the sorghum under drought stress during the months of June, July, and August.

The experiments at Powhattan were planted in a clay loam soil, where the previous crops were wheat and soybeans, respectively. Dates of planting for 1969 and 1970 were June 4 and June 23, respectively.

Good soil moisture conditions existed at Powhattan both years during planting, with 1970 being the drier of the two years. April of 1969 had almost 2 inches of rain above normal and May had 1 inch above normal. April and May of 1970 both had below normal rain fall. The precipitation for the first 60 days after planting in 1969 totaled 9.93 inches, while in 1970 it totaled only 3.33 inches. Here, as in Ashland, hot, dry winds put the sorghum under a drought stress condition.

Mechanical weed control was used at Powhattan in 1969. This consisted of rotary hoeing the sorghum when it was about 2 inches high and several sweep cultivations during the early part of the growing season. Weed control at Manhattan was made by herbicide spray and rotary hoeing and three mechanical cultivations. Some hand hoeing was also necessary. In 1969, atrazine was applied at the rate of 1.5 pounds of active ingredient per acre to the experiment at Manhattan, where weeds presented a special problem.

In 1970, the seedbed at Powhattan was treated with a preplant herbicide which all but eliminated further measures of weed control, except some hand hoeing. Weeds were not a problem at Ashland in 1970 because of a preplant herbicide spray. Cultivation and some hand hoeing were adequate for proper weed control.

A complete randomized block design with 2 replications was used in this experiment. Each plot of the first experiment at each location consisted of 3 rows 22 feet long, of which only 20 feet of the center row was collected for data. The second experiment consisted of 3 rows 44 feet long with plants 12 inches apart of which only 40 feet of the center row were used in data measurements.

Agronomic traits studied in this experiment were:

Stomatal numbers were obtained by the use of a microscope at the magnification of 7.5X by 20X and counted directly. Three areas of the 6th leaf (flag leaf being counted as number one) were used; base, middle, and tip with 5 readings from each area. The 6th leaf was chosen for this study because in a preliminary study the stomatal number of the 6th leaf was found to be the most highly correlated to the number per unit area of the entire leaf surface of the plant. Only the stomata on the lower surface of the leaves were counted because of the position of the stomata and ease of counting.

A 20-foot section of each plot was harvested for yield in the first experiment, and 40-foot for the second experiment. Heads were removed by hand with a linoleum knife and later threshed with a small-plot thresher. The amount of grain per harvested area was recorded and a moisture meter reading taken and the grain was adjusted to 10% for net yield.

Half bloom date was recorded as the number of days from seeding to anthesis of 50% of the plants in each testing plot.

Head number was determined by counting the number of harvestable heads in the 20 foot and 40 foot section to be harvested.

Peduncle diameter was measured 2.5 cm (1 inch) below the panicle base with micrometer calipers after anthesis of the entire head.

Plant height was measured in centimeters from ground level to the collar of the flag leaf for 20 plants in each plot. The average height was then used for each testing plot.

Total leaf number was recorded after marking every fifth leaf starting with the coleoptile. The total number of leaves was recorded after anthesis.

Kernel number per plant was calculated by counting the number of seeds in a 25 gram sample with a electronic seed counter and adjusting this to 10% moisture level.

Kernel weight per 1000 seeds was arrived at by taking the number of seeds per 25 grams of each plot and converting it to a 1000 seed level, at 10% moisture.

Leaf area in this experiment was the average leaf area of the fourth and fifth leaves (flag leaf as number one). The leaf area was determined by measuring the length and width and multiplying by a factor of .75. The fourth and fifth leaves were found to be the most highly correlated pair of leaves in relation to the total leaf area in a preliminary study. The measurements were taken after the appearance of the flag leaf and leaf growth had stopped.

### STATISTICAL ANALYSIS

Statistical analysis were made on a plot means according to the methods outlined by Fryer (1966) for multiple linear regression analysis. In some statistical studies, it is advantageous to consider 2 or more types of numerical measurements simultaneously, because they may be related to the dependent variable and related to each other. For example, in this study, it was desired to see what degree of relationship existed between the dependent variable, grain yield, and the independent variables, plant height, kernel number, kernel weight, leaf number, leaf area, peduncle diameter, stomate number, head number, and half bloom date.

The multiple regression model situation assuming that "y" is linearly related to 2 or more X's or  $X_1, \dots, X_s$ , is:

$$Y = \beta_0 + B_1 (X_1 - \mu_1) \dots B_s (X_s - \mu_s) + E$$

where:

Y is the dependent variable

$\beta_0$  is a constant

$B_1$  is the slope of the regression plane in the  $X_1$  direction

$X_1$  is the first independent variable

$\mu_1$  is the mean of  $X_s$

$B_s$  is the slope of the regression plane in the  $X_s$  direction

$X_s$  is the "s" independent variable

$\mu_s$  is the mean of  $X_s$

E is the amount by which the point  $(X_1, X_s, Y_{ijk})$  is above or below the regression surface

The coefficient of determination,  $R^2$ , was estimated in order to evaluate the relationship of the 9 independent variables with the dependent variable. The amount of contribution of each variable to the  $R^2$  was also calculated.

$R^2$  is the fraction of the total sum of squares of Y attributable to the independent variables. In other words,  $R^2$  explains what portion of the observed variability among the Y's, as measured by  $\sum(y^2)$ , is assignable to multiple linear regression on the included variables. If the  $R^2$  is large, most of the variation in "Y" is explained by the variables already included. If the  $R^2$  is low, the variation in "Y" is mostly unexplained due to random variation or other important variables not included in the regression.

## RESULTS AND DISCUSSION

### STOMATAL NUMBERS AND YIELD

The stomata are openings in the epidermis bounded by two specialized epidermal cells (guard cells) which by changes in shape bring about the opening and closure of the aperture. The stomata, therefore, control the in-flow and out-flow of gases to the leaves of plants. A greater number of stomata would allow a entrance of more  $\text{CO}_2$  and thus increase the overall yield of the plant. This is an oversimplification, as many factors could influence this action, such as size of stomata, and environmental conditions. However, this investigation was designed to see if a correlation does exist between stomata numbers and yield. The correlation coefficients between stomata numbers and grain yield are given in Table 1.

In 1969, 3 different techniques were utilized to calculate stomatal density. The first method gave equal weight to the tip, middle, and base of the leaf, with 5 readings from each. This number was then adjusted to stomates per  $\text{mm}^2$  and multiplied by the leaf number and leaf area for total stomata number. The second method only utilized the center portion of the leaf which was multiplied by leaf number and leaf area. The third method included only stomate number per  $\text{mm}^2$  without any use of leaf number or leaf area. Simple correlation coefficients were then computed between these 3 outcomes and grain yield. However, none of these 3 investigations gave significant or near significant correlation coefficients.

The highest correlation indicated that only 3.00% of the variation in grain yield could be accounted for by stomata number. This leads to two conclusions (1) There was no correlation between stomate number and grain yield, or (2) Error overshadowed the outcome and produced no association where one does exist.

Table 1. Simple correlation coefficients for stomate numbers vs grain yield for 2 locations, 2 years, and for 2 different plant spacings of grain sorghum.

Variable:	Manhattan		Ashland		Powhattan	
	1969	12-inch	6-inch	12-inch	1969	1970
Grain yield with:						
Total stomate number	.088	-.044	-.138	.141	.089	.174
Stomate (center portion only)	.103	-.131	-.192	.148	.061	.128
Stomate density	.025	-.016	-.132	.066	-.009	-.127
					-.345	-.267
					-.386	-.135
					-.275	.102

It is reasonable that a correlation does exist because it has been shown to exist in other monocotyledon plants. Teare (1969) from an investigation with wheat (Triticum vulgare) concluded that for a high yielding variety, 10,500 stomates per  $\text{cm}^2$  was required for the flag leaf.

It was found in grain sorghum that stomata number increased from the base of the leaf to the tip in all hybrids. The size of the stomata also changed and seemed to become larger as their position neared the tip. Numbers did not increase significantly from the midrib to the edge. However, size did appear to be smaller, nearer the midrib.

Error in this investigation could have been included by many factors. Of these the most important ones are: 1) Differences in size of stomata, 2) Exact position on leaf where the three samples were collected, (tip, middle, and base) where differing lengths of leaves of different hybrids caused difficulty, 3) Closeness to midrib, with different widths of hybrids, 4) Error in the actual counting of stomata under the microscope, and 5) The choice of leaf from which to sample. The 6th leaf was chosen for sampling because in a preliminary study using RS 610, it exhibited the highest correlation for stomate number to the total stomate number of the plant. The samples from the 6th leaf showed the highest correlation to the total stomate number of the plant. This variety has approximately 20 to 21 leaves per plant. However, in hybrids of this investigation leaf number varied from 18 to 22, and the 6th leaf might not have been the best choice in all cases.

Generally, the association, low as it was, did increase from the 6 inch spacing to the 12 inch spacing, however, not enough increase was noted to draw any substantial conclusions.

### MULTIPLE LINEAR REGRESSION

The relative magnitudes of several yield components contributing to grain yield were computed by  $R^2$ .  $R^2$  is a measure of the goodness of fit of regression from a group of independent variables. Table 2 shows the multiple linear regression of the dependent variable grain yield and the other 9 independent variables.

The coefficients of determinations,  $R^2$ , were very high and consistent in all of the cases investigated. They were all of the magnitude of 0.943 to 0.995, which indicate that most of the variation in grain yield could be explained by the independent traits included in the investigation. However, considering both spacings, locations, and years almost all of the  $R^2$  was attributable to 2 variables, specifically kernel number per plant and kernel weight. With kernel number contributing approximately twice that of kernel weight. Contributions by the other 7 independent variables, head number, leaf number, half bloom date, peduncle diameter, plant height, leaf area, and stomata number, were not significant.

### STANDARD PARTIAL REGRESSION

Estimation of the standard partial regression coefficient provides a means of distinguishing magnitudes of single effects from complex associations. The standard partial regression coefficient also measures the relative importance of each causal factor, whereas correlation simply measures mutual association without regard to relative importance.

The obtained standard partial regression coefficients for both locations, spacings, and years are given in Table 3. In all cases investigated, the coefficients obtained for kernel number and kernel weight were high and

Table 2. Multiple linear regression of yield on 9 independent variables for 2 locations, 2 years with 2 different plant spacings of grain sorghum.

Variable:	Manhattan			Ashland			Powhattan					
	1969	12-inch	6-inch	1970	6-inch	12-inch	1969	6-inch	12-inch	1970	6-inch	12-inch
$R^2$												
Contribution to $R^2$ :												
Kernel number	.677	.694	.516	.678	.647	.578	.889	.929				
Kernel weight	.310	.289	.407	.302	.332	.403	.103	.059				
Head number	.000	.000	.000	.000	.000	.000	.001	.001				
Leaf number	.000	.000	.002	.004	.003	.000	.000	.000				
Half-bloom	.000	.001	.001	.001	.001	.002	.000	.000				
Peduncle diameter	.000	.000	.001	.000	.000	.000	.000	.000				
Plant height	.000	.001	.000	.000	.000	.000	.000	.000				
Leaf area	.001	.000	.000	.003	.000	.001	.001	.000				
Stomate number	.000	.001	.004	.001	.000	.000	.000	.000				

Table 3. Standard partial regression coefficients of yield on 9 other variables for 2 locations, 2 years with 2 different plant spacings of grain sorghum.

Variable:	Manhattan			Ashland			Powhattan					
	1969	12-inch	6-inch	1970	12-inch	6-inch	1969	12-inch	6-inch	1970	12-inch	6-inch
Kernel number	.96**	1.00**	1.12**	1.17**	1.15**	.88**	.83**	.80**	.80**	.80**	.80**	.80**
Kernel weight	.58**	.56**	.76**	.60**	.61**	.60**	.34**	.28**	.34**	.28**	.28**	.28**
Head number	.01	-.02	.02	.02	.01	-.05	.04	.01	.04	.01	.01	.01
Leaf number	.00	-.11	-.33**	.06	-.08	.06	.02	.00	.02	.00	.00	.00
Half-bloom	-.02	-.06	-.18	-.08	-.04	-.07	.00	-.01	.00	-.01	-.01	-.01
Peduncle diameter	-.02	.00	.03	-.01	.01	.02	.00	-.01	.00	-.01	-.01	-.01
Plant height	.02	.04	-.01	-.04	.00	.01	.03	.04	.03	.04	.04	.04
Leaf area	.04	-.18	-.61**	.16	-.09	.06	.00	-.06	.00	-.06	-.06	-.06
Stomate number	.03	.04	.12	-.07	-.01	-.02	.00	-.12	.00	-.12	-.12	-.12

\*\* Significant at 1% level

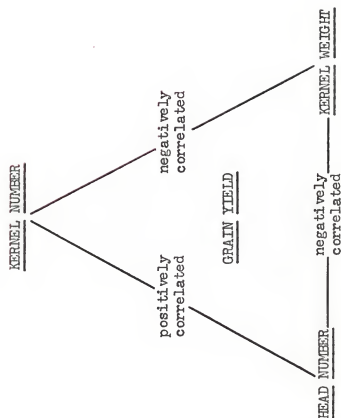
significant, with the other 7 agronomic traits contributing practically nothing. These results are identical with those of the multiple linear regression coefficient analysis.

#### INTERACTIONS AMONG KERNEL NUMBER, KERNEL WEIGHT, AND HEAD NUMBER

Since the interrelationships of kernel number, kernel weight, and head number are of a special case, these relationships will be discussed first with the remainder of the relationships following.

The interactions among kernel number, kernel weight, and head number are complex, as the amount of nutrients, etc. are increased (6 inch plant spacing to 12 inch), the association of kernel number with head number increases and the association between kernel number and kernel weight fluctuates but not in any specific pattern. In 3 of the 4 investigations kernel number was found to be negatively significantly correlated with kernel weight. Head number was found to be positively correlated with kernel number, but not significantly in all investigations. This would indicate that head number would be negatively correlated with kernel weight, but in these investigations this could not be substantiated. These interrelationships are shown in Diagram 1. Seeds per head is usually considered to be the most highly correlated with grain yield. However, in these investigations seeds per whole plant were measured instead of seeds per head. This would mean that if there was an association between head number and yield some of this relationship would be included in the correlation of kernel number with grain yield. These correlation coefficients are given in Table 4. At the 6 inch spacings the correlations of head number to grain yield are nearly zero, therefore, head number could not be contributing much toward the relationship of kernel number to grain yield. However, in

Diagram 1. Interrelationships of the main components of yield; kernel number per head, kernel weight, and head number.



the 12 inch investigations, head number is positive and significantly correlated with grain yield, therefore it is or could be contributing to the correlation of kernel number and grain yield. Head number could contribute to the relationship of kernel number per head with grain yield if the average kernel weight per seed is different in the tiller heads or between the harvested tiller heads and the main head.

At Powhattan in 1970 a positive and significant correlation was found between kernel number and kernel weight. This discrepancy from the other correlations could have been caused by climatic conditions; temperature, sub-soil moisture, or specific dates of rainfall, interacting with the developmental growth of the sorghum hybrids.

#### INTERRELATIONSHIPS AMONG TRAITS

Interrelationships among agronomic traits are of considerable value for planning and evaluating breeding programs. A knowledge of these interrelationships is valuable because it provides a basis for the development of selection indexes for the simultaneous improvement of traits, for avoiding selection of undesirable traits, and for efficient selection of traits with low heritabilities. Since grain yield has a low heritability in grain sorghum (Liang 1968), it is of great value to know the traits which are highly associated with it to maintain a highly effective breeding program for grain yielding capacity.

Simple correlation coefficients among traits were computed (Tables 5,6,7, and 8) for all pairs of traits for the 36  $F_1$  hybrids for 2 years, 2 locations, with 2 different plant spacings. Associations between these traits were variable but did show some significant interactions.

Table 4. Simple correlation coefficients for kernel weight and kernel number for 2 locations, 2 years, and for 2 different plant spacings of grain sorghum.

Variable:	Manhattan		Ashland		Powhattan	
	1969	1970	1969	1970	1969	1970
	6-inch	12-inch	6-inch	12-inch	6-inch	12-inch
Kernel number with:						
Kernel weight	-.257	-.363	-.538	-.529	-.513	.311
Head number	-.034	.444	.280	.512	.077	.152
Kernel weight with:						
Head number	.096	.003	-.061	-.234	.130	-.100
Grain yield with:						
Head number	.035	.157	.276	.452	.193	.128
						.325

Table 5. Simple correlation coefficients among all pairs of traits for 36  $F_1$  hybrids combined for 2 locations, 2 years, and for 2 different plant spacings of grain sorghum at Manhattan, Kansas, for 1969.

	grain yield (1)	kernel number (2)	kernel weight (3)	head number (4)	leaf number (5)	half bloom date (6)	peduncle diameter (7)	plant height (8)	leaf area (9)	stomate number (10)
(1)		.833	.198	.157	-.100	-.695	.049	.163	-.106	-.044
(2)	.823		-.363	.144	.051	-.573	-.068	.235	-.119	-.007
(3)	.327	-.257		.003	-.260	-.139	.184	-.169	.052	-.075
(4)	.035	-.034	.096		.062	-.380	-.307	.192	-.306	-.242
(5)	-.112	-.187	.112	.067		.194	-.072	.427	-.101	.465
(6)	-.088	.009	-.195	-.046	.603		.024	.164	.447	.360
(7)	-.010	.095	-.162	-.093	-.524	-.430		.115	.223	.213
(8)	-.153	.052	-.383	-.025	.355	.552	-.145		.020	.125
(9)	.223	.329	-.226	-.102	-.116	.288	.192	.074		.513
(10)	.088	.104	-.083	.015	.200	.364	.061	.256	.467	

Upper diagonal is the data from the 12 inch spacing and the lower diagonal is the data from the 6 inch plant spacing.

Table 6. Simple correlation coefficients among all pairs of traits for 36 F<sub>2</sub> hybrids combined for 2 locations, 2 years, and for 2 different plant spacings of grain sorghum at Powhattan, Kansas, in 1969.

grain yield (1)	kernel number (2)	kernel weight (3)	head number (4)	leaf number (5)	half bloom date (6)	peduncle diameter (7)	plant height (8)	leaf area (9)	stomate number (10)
(1)	.760	.471	.150	-.216	-.407	.361	-.125	.452	.174
(2)	.805	-.198	.165	-.270	-.175	.368	.155	.229	.043
(3)	.081	-.513	.037	.054	-.342	.022	-.405	.344	.221
(4)	.193	.077	.129	-.057	-.348	.023	-.032	.306	.272
(5)	.035	.227	-.364	-.160	.599	-.652	.076	-.449	-.051
(6)	.081	.202	-.381	-.131	.678	-.363	.186	-.466	-.044
(7)	.344	.207	.106	.397	-.414		-.141	.543	-.096
(8)	.224	.362	-.273	.120	.320	.065		-.286	-.185
(9)	.136	-.211	.534	.118	-.534	.392	-.351		.142
(10)	.089	-.066	.274	-.058	-.020	.141	-.058	.324	

Upper diagonal is the data from the 12 inch spacing and the lower diagonal is the data from the 6 inch spacing.

Table 7. Simple correlation coefficients among all pairs of traits for 36  $F_1$  hybrids combined for 2 locations, 2 years, and for 2 different plant spacings of grain sorghum at Ashland, Kansas, for 1970.

	grain yield (1)	kernel number (2)	kernel weight (3)	head number (4)	leaf number (5)	half bloom date (6)	peduncle diameter (7)	plant height (8)	leaf area (9)	stomate number (10)
(1)		.822	.031	.452	.084	-.005	-.141	.163	.154	.141
(2)	.719		-.529	.512	.213	.282	.093	.333	.133	.262
(3)	.151	-.538		-.234	-.161	-.415	-.374	-.257	.003	-.170
(4)	.276	.280	-.061		.033	.143	-.212	-.024	-.057	.088
(5)	-.087	-.049	.020	.143		.823	.248	.813	.594	.728
(6)	-.258	.000	-.276	.144	.762		.310	.765	.531	.681
(7)	.106	.147	-.104	-.190	-.039	.033		.367	.370	.269
(8)	.100	.136	-.034	.155	.795	.640	.052		.602	.702
(9)	-.120	-.136	.080	.134	.668	.592	.147	.574		.649
(10)	-.138	-.041	-.127	.199	.653	.720	.064	.588	.684	

Upper diagonal is the data from the 12 inch spacing and the lower diagonal is the data from the 6 inch plant spacing.

Table 8. Simple correlation coefficients among all pairs of traits for 36  $F_1$  hybrids combined for 2 locations, 2 years, and for 2 different plant spacings of grain sorghum at Powhattan, Kansas, for 1970.

grain yield (1)	kernel number (2)	kernel weight (3)	head number (4)	leaf number (5)	half bloom date (6)	peduncle diameter (7)	plant height (8)	leaf area (9)	stomate number (10)
(1)	.964	.684	.325	.013	-.603	-.621	-.117	-.362	-.265
(2)	.943	.491	.369	.071	-.530	-.544	-.085	-.282	-.181
(3)	.598	.312	-.036	-.275	-.591	-.550	-.295	-.463	-.440
(4)	.128	.152	-.097	.187	-.118	-.335	.095	-.144	-.117
(5)	-.266	-.174	-.380	.052	.458	.232	.596	.518	.723
(6)	-.613	-.506	-.566	.127	.595	.512	.702	.666	.543
(7)	-.343	-.237	-.370	-.109	.472	.353	.666	.570	.692
(8)	-.220	-.149	-.343	.100	.471	.208	.425	.814	
(9)	-.288	-.146	-.436	.125	.600	.650	.624		
(10)	-.345	-.213	-.474	.079	.718	.585			

Upper diagonal is the data from the 12 inch spacing and the lower diagonal is the data from the 6 inch spacing.

Grain yield was highly associated with kernel number consistently in all of the investigations, with kernel weight being associated frequently in both 6 and 12 inch spacings. In these 12 inch spacing a killing frost caught the plants before full maturity, thus causing a decrease in grain yield, which should not have been shown if frost had not stopped their development.

Half bloom date was found to be negatively correlated with kernel number at the 12 inch spacings, but slightly positively correlated at the 6 inch spacings. This is reasonable, because if the plants are crowded a later blooming plant would not necessarily have more seeds, however, with wider spacing a plant would have more nutrients, etc. available and would benefit with a later blooming date provided the growing season was long enough for the seeds to develop. This caused the discrepancy between this investigation and earlier investigations (Liang 1969, Niehaus and Pickett 1966) where the association between half bloom date and grain yield were positive.

Peduncle diameter, half bloom date, and leaf number show complex inter-relationships (Diagram 2). Half bloom date and leaf number are positive and significantly correlated. Sorghum is a species of plant which exhibits terminal inflorescence, or continues to initiate leaves until the panicle is initiated. If floral initiation is delayed, more leaves will be produced. Thus, when half bloom date is lengthened, more leaves will be initiated producing a positive correlation. Peduncle diameter and half bloom date are negatively correlated. With a limited growing season sorghum plants that mature later will not produce peduncles as large as those which undergo floral initiation earlier.

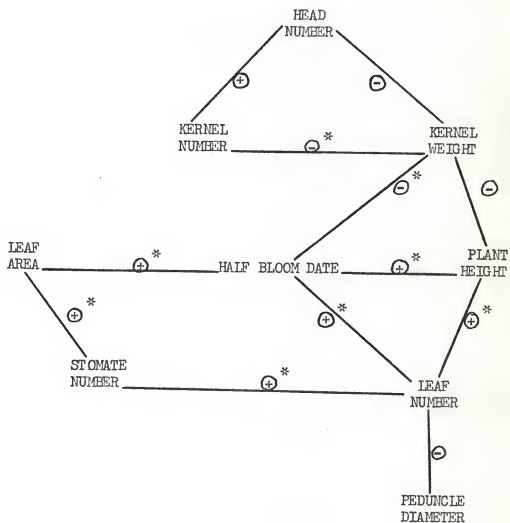
Plant height is positive and significantly correlated to leaf number and to half blooming date. If floral initiation is delayed and more leaves are produced, increased height of the stalk also occurs.

In all investigation except at Powhattan in 1969, leaf area was positive and significantly correlated with half bloom date. This indicates that later blooming varieties have larger leaf areas. However, the association between leaf area and leaf number was highly variable which indicates that leaf number and leaf area appear to develop by separate functions and do not interact significantly.

Stomate number per plant was variable throughout these investigations and was positive and significantly correlated only with leaf number and leaf area. It was associated with plant height but only significant in 2 of the 8 investigations.

The associations determined by this investigation were found using specifically the 36  $F_1$  hybrids named elsewhere in this paper. Within this group of grain sorghum hybrids the maturity dates varied from early to late maturing ones which did not have a long enough growing season to fully mature at the locations used in this investigation. This along with other factors make the associations determined in this investigation true only for the collective 36  $F_1$  hybrids used and not necessarily for different years or locations.

Diagram 2. Interrelationships among agronomic traits of grain sorghum, found in this investigation.



⊕ - positive correlation

⊖ - negative correlation

\* - significant

## SUMMARY AND CONCLUSIONS

Thirty-six  $F_1$  hybrids were randomly selected and planted at 2 different locations, for two consecutive years (1969 and 1970), and under 2 different plant spacings, 6 and 12 inches, respectively.

Studies were conducted on the interrelationships of 10 agronomic traits. Simple correlation coefficients were obtained in order to estimate the interrelationships of all pairs of traits in this study. Multiple regression and standard partial regression coefficient analysis were made to determine the relationship and relative importance among yield components to grain yield.

Grain yield showed a significant positive correlation with kernel number. Kernel weight was significantly correlated in some replications but not in all of the replications. Half bloom date was significantly negatively correlated with grain yield at the 12 inch spacing both years and locations but not at the 6 inch spacing. Grain yield with head number was variable and tended to be positive, in all of the experiments. Peduncle diameter was highly correlated with grain yield at Powhattan in 1969 but not at Manhattan. In this case a genetic-environment interaction could have taken place. The last half of the growing season was dry and kept grain yield lower and allowed a significant correlation to take place in 1969. There were no other high correlations between grain yield and other agronomic traits studied.

Negative significant correlations were found between kernel number and kernel weight. These correlation coefficients varied from highly negative to not quite significant. At Powhattan in 1970, kernel weight was found to be positively correlated with kernel number. This deviation from the other three interaction outcomes could be due to a climatic interaction with the developmental sequence of the sorghum hybrids.

Interrelationships found in this investigation included: half bloom date was positively correlated with leaf number, plant height, and leaf area; peduncle diameter was negatively correlated with half bloom date and leaf number; half bloom date was negatively correlated with kernel number and kernel weight; and plant height was negatively correlated with kernel number. Interrelationships of other agronomic traits were highly variable throughout this investigation. However, leaf area and leaf number was significantly positively correlated with stomate number per plant. This was to be expected because leaf area and leaf number are functions of stomate number determined in this investigation.

$R^2$  values of grain yield, computed from multiple regression analysis with 9 other traits, were high. With kernel number and kernel weight contributing comparatively more than the rest of agronomic traits included in the investigation. Standard partial regression coefficient of kernel number and kernel weight were high and significant, with kernel number contributing nearly twice that of kernel weight in their relation to grain yield.

## LITERATURE CITED

1. Adams, M. W. 1967. Basis of yield component compensation in crop plants with special reference to the field bean, Phaseolus vulgaris. Crop Science 7:505-510.
2. Atkins, R. E., V. H. Reich, G. M. Beil, and J. S. Kirby. 1968. Inter-relationships among dry weight of panicles, threshing percentage, and grain yield in sorghum. Agron. J. 60:219-222.
3. Birdsall, J. E. and K. W. Neatby. 1944. Researches on drought resistance in spring wheat: size and frequency of stomata in varieties of Triticum vulgare and other Triticum spp. Can. J. Res. 22:38-51.
4. Blum, A. 1967. Effects of soil fertility and plant competition of grain sorghum panicle morphology and panicle weight components. Agron. J. 5:400-403. (Israel)
5. Casady, A. J. and others. 1965. Effect of a single height (Dw) gene of sorghum on grain yield, grain yield components, and test weight. Crop Sci. 5:385-388.
6. Cowart, F. E. 1936. Apple leaf structure as related to position of the leaf upon shoot and type of growth. Proc. Soc. Hort. Sci. 33:145-148.
7. Dalton, L. G. 1967. A positive regression of yield on maturity in sorghum. Crop Sci. 7:271-272.
8. Dobrenz, A. K., L. Neal Wright, A. B. Humphrey, M. A. Massengale, and W. R. Kneebone. 1969. Stomate density and its relationship to water-use efficiency of Blue Panicgrass (Panicum antidotale Retz). Crop Science 9:354-357.
9. Dunn, D. B. 1965. Stomatal patterns of dicotyledons and monocotyledons. Am. Midland Nat. 74:185-195.
10. Eckerson, S. H. 1908. The number and size of stomata. Bot. Gaz. 46:221-224.
11. Freeland, R. O. 1948. Photosynthesis in relation to stomatal frequency and distribution. Plant Physiology 23:595-600.
12. Fryer, H. C. 1966. Concepts and methods of experimental statistics. 1st ed. Allyn and Bacon, Inc., Boston, Mass.
13. Hesketh, J. D. 1963. Limitations to photosynthesis responsible for differences among species. Crop Sci. 3:493-498.
14. Hunt, L. A. and B. R. Christie. 1969. Determination of stomatal numbers, stomatal lengths, and dry weight increments of detached Bromegrass leaves. Can. J. Plant Sci. 49:597-602.

15. Kirby, J. S., and R. E. Atkins. 1968. Heterotic response for vegetative and mature plant characters in grain sorghum, Sorghum bicolor (L.) Moench. Crop Sci. 8:335-339.
16. Liang, G. H. 1967. Diallel analysis of agronomic characters in grain sorghum, Sorghum vulgare Pers. Can. J. Genet. Cytol. 9:269-276.
17. Liang, G. H., E. G. Heyne, J. H. Chung, and Y. O. Koh. 1968. The analysis of heritable variation for three agronomic traits in a 6-variety diallel of grain sorghum, Sorghum vulgare Pers. Can. J. Genet. Cytol. 10:466-469.
18. Liang, G. H. L., C. B. Overley, and A. J. Casady. 1969. Interrelations among agronomic characters in grain sorghum, (Sorghum bicolor Moench). Crop Sci. 9:299-302.
19. Martin, J. H. 1928. Plant character and yield in grain sorghum. J. Am. Soc. Agron. 20:1177-1182.
20. Miller, E. C. 1938. Plant Physiology. 2nd ed. McGraw-Hill Book Co., Inc., New York and London.
21. Muenscher, W. L. C. 1915. Relationships of stomatal frequency and size. Am. J. Botany. 2:487-504.
22. Niehaus, M. H., and R. C. Pickett. 1966. Heterosis and combining ability in a diallel cross in Sorghum vulgare Pers. Crop Sci. 6: 33-36.
23. Peterson, D. 1929. On the stomata of Rumex acetosa L. Bot. Gaz. 29: 175-193.
24. Quinby, J. R. 1963. Manifestation of hybrid vigor in sorghum. Crop Sci. 3:288-291.
25. Rao, S. B. P., H. P. Bhatia, and K. B. Kulkarni. 1965. Correlation studies in hybrid sorghums. Sorghum News Letter. 8:23-25.
26. \_\_\_\_\_, V. P. Rao, and D. S. Rajabnooshavan. 1938. Sorghum-size relationships of seed, embryo, seedling and first seedling leaves. Proc. Ind. Acad. Sci. 8(B):151-156.
27. Roovaart, E. V. and G. D. Fuller. 1935. Stomata frequency in cereals. Ecol. 16:278-279.
28. Sieglinger, J. B. 1936. Leaf number of sorghum stalks. J. Am. Soc. Agron. 28:636-642.
29. Smith, H. B. 1941. Variation and correlation of stomatal frequency and transpiration rate in Phaseolus vulgaris. Am. J. Bot. 28:722-750.

30. Stickler, F. C., and A. W. Pauli. 1961. Leaf removal in grain sorghum. I. Effects of certain defoliation treatments on yield and components of yield. *Agron. J.* 53:99-102.
31. Teare, J. L. 1969. Letter of communication, Washington State University, Assistant Professor, Pullman, Washington.
32. Wicks, L. M. 1935. The anatomy of Amaryllidaceae leaves. I. Stomatal distribution in Haemanthus and Brunsvigia. *Annals Bot.* 49:493-505.
33. Yapp, R. H. 1912. *Ulmaria palustris* and its bearing on the problem of xeromorphy in marsh plants. *Annals Botany* 26:815-871.

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## APPENDIX

A-1. Mean data for half bloom date for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing.

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	57	58	53	53	68	67	57	63
T.E. Mucho	59	62	51	51	69	68	55	59
W. M. G-6ly	61	61	53	54	70	69	56	63
G. M. A.	61	63	51	51	69	68	56	70
W. M. 76Y	62	63	56	55	71	69	61	67
RS 671	63	63	54	55	74	71	60	62
RS 702	66	67	63	66	75	73	70	72
RS 633	63	64	53	53	68	69	57	59
RS 626	62	62	51	52	69	69	61	58
RS 625	58	63	51	52	67	68	56	55
Richardson 404SR	63	65	57	57	71	71	63	70
P.U. 685	62	63	55	56	69	71	59	61
Pioneer 820	66	64	57	56	76	70	71	74
Pioneer 845	62	62	53	54	69	67	61	63
P.U. 634	57	63	55	56	68	67	60	63
Pioneer 846	63	64	52	52	72	69	58	66
Pioneer 828	65	65	57	56	74	75	62	75
N.K. 222A	58	61	52	52	67	68	59	61
Excel 707	63	60	53	53	71	68	59	59
Frontier 414	63	64	60	60	72	70	68	71
Frontier 413	63	64	59	59	73	69	63	65
Excel 505	63	59	52	52	70	69	59	56
N.K. 222G	62	61	57	56	68	68	64	70
Dekalb F-64	59	62	56	56	69	69	61	62
NC-T-700	63	62	57	59	73	70	59	64
Asgrow Flare	63	62	52	52	72	71	56	60
N.K. 275	62	60	56	54	70	70	60	60
Horizon 80	63	61	55	54	68	68	60	59
Dekalb E-57	62	64	53	53	69	70	61	62
Asgrow Jumbo C	75	76	79	78	87	86	75	76
Dekalb C-48a	64	65	53	53	71	71	61	61
Advance 91	64	67	60	59	72	71	69	70
Dekalb C-44c	63	66	53	52	71	72	60	59
Advance 76	62	65	52	52	70	70	61	63
Acco R2020	63	63	59	59	73	72	69	69
Acco R109	61	62	53	54	70	70	56	60

A-2. Mean data for half bloom date for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing.

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	59	58	52	53	73	77	58	59
T.E. Mucho	58	57	50	51	76	69	55	55
W. M. G-6ly	59	58	53	54	69	70	62	61
G. M. A.	59	60	50	51	72	69	55	59
W. M. 76Y	63	61	54	55	71	71	65	60
RS 671	64	61	53	55	77	75	61	60
RS 702	66	63	63	62	75	79	71	70
RS 633	57	59	54	55	76	70	56	65
RS 626	60	58	51	50	72	70	60	56
RS 625	58	59	50	51	70	75	55	54
Richardson 404SR	64	61	59	56	74	75	60	62
P.U. 685	62	59	55	54	71	74	59	71
Pioneer 820	64	61	56	59	74	76	65	62
Pioneer 845	60	59	53	53	71	70	62	59
P.U. 634	59	58	55	58	70	72	62	60
Pioneer 846	60	58	51	52	74	72	59	60
Pioneer 828	57	63	59	59	74	75	70	71
N.K. 222A	67	58	53	54	68	76	61	56
Excel 707	61	61	53	53	72	75	58	58
Frontier 414	67	67	60	61	73	75	65	62
Frontier 413	65	68	60	60	76	72	70	64
Excel 505	62	59	51	52	71	69	58	55
N.K. 222G	61	60	59	57	69	69	64	70
Dekalb F-64	62	60	55	56	69	69	62	65
NC-T-700	67	63	58	55	72	77	71	69
Asgrow Flare	64	58	51	51	75	71	59	62
N.K. 275	68	59	54	54	75	69	60	65
Horizon 80	63	59	53	54	76	72	59	58
Dekalb E-57	64	58	52	54	77	77	60	57
Asgrow Jumbo C	70	70	80	83	87	86	78	77
Dekalb C-48a	65	61	52	54	70	76	60	73
Advance 91	67	63	60	60	73	75	65	65
Dekalb C-44c	62	61	51	51	73	72	62	56
Advance 76	63	61	51	54	76	75	62	71
Acco R2020	67	63	55	60	74	76	64	64
Acco R109	62	58	52	54	76	77	61	61

A-3. Mean data for plant height for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing.

Variety	Manhattan		Ashland		Pownhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	81.4	81.0	71.1	69.3	73.5	88.8	78.6	78.4
T.E. Mucho	74.1	78.2	61.0	68.9	75.7	75.7	70.8	70.0
W. M. G-6ly	71.1	74.5	69.8	65.1	72.1	73.5	77.8	72.1
G. M. A.	79.2	74.7	63.6	63.9	68.6	79.8	70.6	93.6
W. M. 76Y	83.7	89.0	79.0	80.8	93.3	94.0	96.7	68.4
RS 671	77.0	77.6	67.3	71.6	85.1	87.5	80.5	81.5
RS 702	77.8	89.2	78.7	77.3	79.9	73.1	83.9	86.1
RS 633	76.8	72.1	66.7	70.5	74.6	74.8	75.5	70.9
RS 626	77.0	73.8	64.1	65.7	81.1	80.7	65.8	69.0
RS 625	79.8	73.6	63.3	61.3	73.7	73.3	67.1	63.9
Richardson 404SR	74.8	85.0	71.6	76.6	80.8	83.4	83.5	77.6
P.U. 685	80.6	77.4	69.8	69.9	84.7	89.4	81.3	78.6
Pioneer 820	74.5	79.7	72.9	71.8	78.4	84.8	88.5	87.5
Pioneer 845	90.2	85.6	81.5	81.9	92.9	102.0	96.3	93.1
P.U. 634	69.6	68.5	62.7	68.4	68.9	72.5	73.2	69.9
Pioneer 846	75.5	74.0	65.7	66.1	74.9	79.2	77.5	74.2
Pioneer 828	86.2	86.1	84.1	79.8	101.9	92.2	91.8	97.5
N.K. 222A	75.9	72.5	68.7	66.9	73.6	74.1	78.1	69.7
Excel 707	75.0	75.4	67.2	70.5	79.9	86.0	79.8	79.4
Frontier 4114	74.3	73.1	70.8	74.8	81.8	83.4	82.7	75.8
Frontier 413	80.6	72.9	72.4	81.4	86.1	89.9	89.5	86.3
Excel 505	74.3	78.8	61.9	69.3	77.1	80.1	75.0	73.6
N.K. 222G	74.7	76.1	66.3	74.4	69.6	72.0	75.8	76.1
Dekalb F-64	79.8	79.8	76.0	79.9	80.7	82.7	79.9	81.2
NC-T-700	74.1	74.9	70.7	71.6	74.2	79.9	76.1	77.6
Asgrow Flare	73.8	73.7	67.2	70.6	78.1	84.4	81.0	72.6
N.K. 275	75.6	78.9	67.5	70.2	83.9	81.7	80.6	78.4
Horizon 80	75.7	78.7	61.6	73.6	83.7	85.5	74.7	75.0
Dekalb E-57	74.8	75.2	64.2	64.7	78.0	78.0	72.3	70.9
Asgrow Jumbo C	101.5	99.6	89.0	86.2	94.6	91.0	84.5	94.4
Dekalb C-48a	82.9	79.4	63.2	70.1	80.2	83.0	83.2	76.2
Advance 91	69.9	83.6	70.3	69.9	70.6	73.0	76.6	74.4
Dekalb C-44c	77.0	79.7	68.3	70.8	82.8	88.9	82.1	77.8
Advance 76	74.3	77.2	66.7	76.1	75.7	80.3	74.9	74.4
Acco R2020	74.0	74.6	67.3	75.0	73.2	78.6	77.2	78.3
Acco R109	74.0	71.0	68.8	69.5	68.1	76.3	70.0	67.6

A-4. Mean data for plant height for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing.

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	80.5	83.5	69.7	68.0	86.7	83.6	72.7	78.5
T. E. Mucho	72.4	73.7	59.5	59.5	78.7	77.4	66.2	69.5
W. M. G-61y	74.1	81.1	68.8	65.6	75.6	77.4	71.0	78.2
G. M. A.	74.3	77.8	60.5	59.1	76.8	80.9	67.9	71.3
W. M. 76Y	91.5	94.7	76.1	75.0	89.9	95.2	87.5	94.0
RS 671	74.1	81.5	68.4	65.1	85.1	83.6	78.1	83.3
RS 702	78.9	84.3	80.4	81.5	80.1	71.5	83.8	86.5
RS 633	69.5	74.4	67.0	65.5	75.7	75.3	70.2	69.8
RS 626	63.3	77.1	65.6	65.5	84.5	80.0	69.2	71.2
RS 625	73.7	75.3	62.6	61.4	76.9	75.8	64.7	66.9
Richardson 404SR	76.7	78.8	71.4	71.3	78.8	78.7	77.3	88.3
P.U. 685	77.3	79.7	70.6	70.7	86.8	81.7	82.3	76.0
Pioneer 820	80.0	87.8	67.4	70.6	83.1	75.0	84.5	87.5
Pioneer 845	89.8	90.1	76.2	74.3	90.1	96.1	96.4	103.5
P.U. 634	65.9	71.1	61.2	61.9	72.1	69.1	70.0	74.5
Pioneer 846	77.5	81.3	62.2	58.3	79.3	78.3	74.6	77.4
Pioneer 828	71.1	96.3	77.0	76.5	92.0	94.0	89.2	95.6
N.K. 222A	88.7	80.8	65.8	63.9	75.3	71.2	70.5	73.3
Excel 707	77.1	78.7	66.3	67.5	82.6	83.8	75.2	76.7
Frontier 4114	77.8	79.7	73.5	74.3	77.9	76.8	75.5	79.7
Frontier 413	84.5	77.3	75.3	75.9	83.9	82.7	82.7	93.2
Excel 505	77.6	78.4	60.3	61.6	80.7	83.0	69.5	78.5
N.K. 222G	72.8	79.9	67.6	68.8	75.7	75.8	78.2	75.3
Dekalb F-64	74.3	78.5	72.9	71.6	83.1	79.7	79.1	79.5
NC-T-700	71.9	82.4	73.6	71.0	77.5	77.5	77.4	82.1
Asgrow Flare	76.6	85.6	65.2	65.9	78.8	81.1	75.3	72.2
N.K. 275	71.9	82.7	68.7	68.1	80.4	82.3	76.3	75.4
Horizon 80	75.9	81.3	64.7	68.2	84.0	82.9	75.7	78.3
Dekalb E-57	71.6	72.7	63.4	64.9	76.6	76.7	67.9	70.8
Asgrow Jumbo C	89.8	93.3	88.4	88.1	101.1	96.6	96.7	92.0
Dekalb C-48a	81.4	83.7	69.0	62.1	86.1	84.7	78.6	87.9
Advance 91	67.7	70.9	64.4	72.6	72.1	71.6	74.3	74.2
Dekalb C-44c	83.4	88.4	61.8	66.6	86.9	86.9	77.5	79.0
Advance 76	76.6	77.9	72.0	66.0	76.4	80.7	75.8	76.6
Acco R2020	76.2	81.7	72.5	70.7	78.5	77.0	72.8	79.6
Acco R109	71.1	81.4	65.0	66.5	72.3	71.1	67.8	72.7

A-5. Mean data for total grain yield for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing (in grams).

Variety	Manhattan 1969		Ashland 1970		Powhattan			
	I	II	I	II	I	II	I	II
WAC 690A	2527	2683	2803	2306	2318	2630	2252	2028
T. E. Mucho	2336	2523	3138	2897	1881	2070	2964	2451
W. M. G-61y	3607	3388	3374	3042	2397	2084	2548	2626
G. M. A.	3027	2785	2795	3146	2100	2353	2969	2362
W. M. 76y	3315	3429	2954	2890	2763	2832	2902	2408
RS 671	2879	2323	3016	3114	2633	2633	2517	2590
RS 702	2953	3011	2856	3062	2565	2362	2297	1789
RS 633	2802	3363	3260	2844	2066	2794	2910	2548
RS 626	3420	2289	2942	2911	2092	2529	2558	2870
RS 625	2553	2970	2672	2490	2299	2229	2912	2382
Richardson 404SR	2916	3369	2774	2704	1960	2414	2325	1976
P. U. 685	3429	3035	2847	2948	2019	2677	2798	3564
Pioneer 820	3345	2993	2498	2472	2417	2165	2420	1028
Pioneer 845	2941	3009	3075	3328	1971	2584	3159	2015
P. U. 634	2788	2919	2521	2574	2169	2594	2874	2052
Pioneer 846	2492	2743	2610	2577	2496	2320	2960	2504
Pioneer 828	3060	3386	2378	2960	2448	1932	3103	1130
N. K. 222A	3222	3649	2406	2525	2545	2552	3141	2226
Excel 707	2876	2710	2674	2820	2300	1847	2231	2428
Frontier 414	3289	3220	2794	2753	2286	3308	2311	2162
Frontier 413	2957	3126	3018	2682	1770	2711	2863	2388
Excel 505	2590	2544	2731	2939	1927	1702	2535	2449
N. K. 222G	2431	3169	2704	3000	2002	2117	2475	2610
Dekalb F-64	2498	2938	2875	3077	2244	1913	2553	2496
NC-T-700	2494	2655	2574	2719	1715	2881	2314	2468
Asgrow Flare	2211	2384	2568	2942	1708	2450	2567	2579
N. K. 275	2733	3058	2366	3047	2086	2481	2729	2943
Horizon 80	2634	2609	2241	3251	2229	2050	2756	2808
Dekalb E-57	3562	3165	2174	2512	2522	2344	2278	2330
Asgrow Jumbo C	2221	1901	2634	1860	2114	2109	1196	0644
Dekalb C-48a	2929	3378	2556	2892	2389	2249	3037	2465
Advance 91	2756	3397	2706	2364	2175	2112	2667	2241
Dekalb C-44c	2932	3371	2822	2754	2418	3135	2472	2361
Advance 76	2626	3011	2153	3008	2164	2091	2236	1119
Acco R2020	2924	2473	2544	2642	1909	2183	2527	2119
Acco R109	3672	3904	2733	3181	2368	2385	2142	2465

A-6. Mean data for total grain yield for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing (in grams).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	5821	6388	5808	6084	4640	5352	4410	4181
T. E. Mucho	5153	4407	4889	4382	4255	4711	5383	4841
W. M. G-61y	6386	7672	6365	5469	5612	6211	5221	5767
G. M. A.	5199	5377	4618	4344	4956	4254	5054	4992
W. M. 76y	5645	5847	5795	4997	5348	5349	4699	4651
RS 671	3857	5805	5517	5565	4608	5444	4583	5158
RS 702	5343	5951	6716	6260	4416	4408	4742	5179
RS 633	5579	4935	5210	4370	3962	4720	4555	3453
RS 626	5839	5583	5105	5206	5383	5487	4358	5559
RS 625	5688	5878	4731	5088	4258	4423	4399	4618
Richardson 404SR	4278	4464	5918	4555	4241	5342	3860	5470
P. U. 685	4397	5648	5361	4897	4727	4934	4221	3432
Pioneer 820	4094	6890	4394	5495	4925	4583	5065	5502
Pioneer 845	4934	6351	5043	5211	3977	4732	5082	5987
P. U. 634	6408	6058	4612	5616	3347	4789	5283	6063
Pioneer 846	5219	5941	3638	5668	5998	4145	5484	5104
Pioneer 828	5245	6112	4762	5433	4268	4606	4472	4194
N. K. 222A	5294	6743	4028	4590	5451	4780	5361	4914
Excel 707	5543	4703	5907	5439	4640	5170	4628	4358
Frontier 414	4393	3838	5790	5045	3662	5266	4096	5450
Frontier 413	4009	2973	4810	4004	4006	4136	4134	5710
Excel 505	4439	4935	5002	4732	4794	5738	4358	5325
N. K. 222G	4724	5286	5134	5668	5979	4732	4515	3848
Dekalb F-64	3623	4347	5747	6063	4922	5543	4566	3399
NC-T-700	3828	4593	4826	5171	5120	4163	4477	4066
Asgrow Flare	3005	5779	5366	6180	4065	4524	4116	3921
N. K. 275	2649	6592	5065	5637	4522	5574	5439	4202
Horizon 80	5234	6633	5210	5548	4533	5064	4353	4940
Dekalb E-57	4074	4187	5511	5507	4934	4565	4317	3962
Asgrow Jumbo C	1960	2611	5183	4935	4000	3100	0816	1368
Dekalb C-48a	5040	4550	5554	4462	5525	4566	4482	2418
Advance 91	3241	3864	4191	5110	5306	4804	4254	4711
Dekalb C-44c	4861	5415	5002	4669	5143	4846	4722	5023
Advance 76	4994	3875	4782	4722	3649	5080	3650	2278
Acco R2020	4434	4383	5366	3583	4108	4618	4347	4342
Acco R109	5914	7204	8360	6427	5662	5429	4139	5086

A-7. Mean data for leaf number for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing (10<sup>-2</sup>).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	1895	1880	1945	1930	1715	1790	1795	1885
T. E. Mucho	2060	2030	1785	1945	1675	1810	1665	1820
W. M. G-6ly	1975	1970	1915	1975	1770	1860	1780	1840
G. M. A.	1935	1930	1820	1815	1710	1735	1610	1905
W. M. 76y	2005	2000	2050	2060	1735	1810	1845	1825
RS 671	2085	2045	1990	2035	1760	1815	1860	1930
RS 702	2210	2175	2160	2160	1840	1925	1975	1835
RS 633	2100	2105	1970	1880	1745	1730	1810	1785
RS 626	2110	2065	1840	1855	1750	1780	1825	1800
RS 625	2090	2075	1790	1855	1750	1785	1750	1645
Richardson 404SR	1935	2080	2010	2060	1720	1810	1960	1800
P.U. 685	1975	2035	1985	1970	1860	1895	1845	1895
Pioneer 820	2200	2265	2065	2080	2080	1990	1995	1910
Pioneer 845	2060	2190	2010	2045	1920	1830	1945	1960
P.U. 634	1855	2005	1940	2035	1810	1750	1925	1975
Pioneer 846	2175	2240	1975	2000	2000	1865	1855	1880
Pioneer 828	2160	2175	2100	2055	1925	1890	1930	2025
N.K. 222A	1915	1915	1920	1980	1750	1720	1875	1765
Excel 707	2000	1930	1865	1960	1750	1785	1835	1835
Frontier 414	1995	1965	2040	2075	1725	1785	1945	1860
Frontier 413	1990	1950	2040	2080	1725	1815	1890	1995
Excel 505	2145	1980	1830	1830	1695	1835	1780	1665
N.K. 222G	2115	2040	2010	2090	1765	1855	1935	1940
Dekalb F-64	2040	1975	2005	2040	1790	1850	1890	1875
NC-T-700	1960	1985	1955	2010	1815	1790	1915	1930
Asgrow Flare	2090	2100	1885	1965	1955	1935	1755	1815
N.K. 275	1970	1915	2000	1935	1755	1810	1840	1880
Horizon 80	2030	1890	1910	2025	1720	1755	1810	1815
Dekalb E-57	2065	2095	1855	1830	1830	1855	1750	1830
Asgrow Jumbo C	2165	2265	2170	2265	2020	2380	2025	1980
Dekalb C-48a	2140	2170	1885	1915	1865	1915	1810	1785
Advance 91	2005	2045	2020	2020	1835	1810	1900	1850
Dekalb C-44c	2025	2055	1860	1875	1885	1920	1865	1735
Advance 76	2110	2170	1970	2000	1870	1930	1760	1815
Acco R2020	1970	1980	2030	2090	1830	1815	1875	1880
Acco R109	1940	2075	1890	1975	1775	1830	1685	1815

A-8. Mean data for leaf number for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing ( $10^{-2}$ ).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	1940	2035	1970	1920	1870	1950	1745	1775
T. E. Mucho	1995	2055	1860	1810	1940	1860	1650	1725
W. M. G-61y	1910	1850	1995	1940	1875	1965	1800	1800
G. M. A.	1995	1905	1820	1850	1920	1860	1690	1700
W. M. 76y	1975	1955	1960	2005	1930	1820	1900	1880
RS 671	2020	1995	1930	1970	1965	1985	1855	1805
RS 702	2145	2040	2145	2240	1920	2110	2005	1960
RS 633	1995	1885	1860	1950	1990	1910	1815	1640
RS 626	1950	2015	1915	1880	1920	1905	1775	1745
RS 625	1985	1850	1780	1830	1930	1945	1625	1625
Richardson 404SR	1980	1990	2015	2005	1860	1955	1890	2000
P.U. 685	2000	2030	1980	2000	1815	1910	1800	1720
Pioneer 820	2195	2025	2130	2095	2080	2160	1985	2025
Pioneer 845	2080	1985	2045	2015	1910	1910	1880	1980
P.U. 634	1845	1815	1950	2005	1935	2020	1970	1940
Pioneer 846	2205	2195	1930	1980	2120	2065	1760	1860
Pioneer 828	1925	2025	2095	2095	2010	2135	1960	1835
N.K. 222A	2130	1995	1970	1880	1810	1885	1905	1835
Excel 707	1940	1940	1870	1905	1870	1945	1855	1770
Frontier 414	1960	2000	2070	2095	1855	1890	1980	1830
Frontier 413	1915	1885	2090	2130	1840	1925	1890	1905
Excel 505	1995	2040	1820	1845	1930	1840	1780	1755
N.K. 222G	1980	2000	2065	2120	1885	1960	1970	1870
Dekalb F-64	1865	1880	1930	2070	1905	1885	1935	1710
NC-T-700	1915	2055	2055	2020	1810	1975	1920	1825
Asgrow Flare	1970	1960	1855	1940	1980	2105	1745	1655
N.K. 275	1865	1925	1925	1930	1935	1755	1820	1655
Horizon 80	1900	1845	1960	1975	1930	1845	1840	1825
Dekalb E-57	1930	1875	1850	1885	2040	2005	1745	1770
Asgrow Jumbo C	2115	2200	2345	2275	2130	2195	2030	2005
Dekalb C-48a	2065	1910	1865	1910	1910	2035	1870	1755
Advance 91	1895	1920	2020	2030	1830	1965	1975	1825
Dekalb C-44c	2025	1980	1820	1820	2005	2060	1910	1720
Advance 76	2010	2020	2015	2070	2100	2050	1890	1785
Acco R2020	1960	2000	2040	2055	1830	1970	1745	1820
Acco R109	1930	2035	1945	1985	2070	2110	1790	1720

A-9. Mean data for kernel number for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing. ( $10^6$ ).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	895	969	1094	800	803	987	986	877
T. E. Mucho	746	809	1154	1072	716	747	1196	999
W. M. G-61y	1017	941	1062	980	690	599	1057	1056
G. M. A.	854	833	1005	1002	734	821	1189	1038
W. M. 76y	1133	1094	1024	1001	905	967	1177	958
RS 671	852	709	1208	1126	917	870	1075	1085
RS 702	954	956	1156	1402	956	906	1081	835
RS 633	870	1024	1230	1117	806	1042	1128	925
RS 626	979	619	1017	1072	725	901	1078	1226
RS 625	881	891	974	916	961	868	1202	888
Richardson 404SR	937	1108	951	912	668	863	1064	862
P.U. 685	1071	902	1093	1068	720	970	1177	1448
Pioneer 820	1066	919	866	791	816	741	1063	548
Pioneer 845	931	920	1059	1136	737	946	1267	773
P.U. 634	860	794	843	839	711	855	1198	824
Pioneer 846	666	832	980	935	813	765	1256	1054
Pioneer 828	836	947	774	926	789	634	1174	555
N.K. 222A	905	941	755	823	870	893	1150	839
Excel 707	888	851	1109	1103	783	761	910	995
Frontier 414	1077	1141	919	914	774	1224	956	931
Frontier 413	1024	1060	1051	944	644	1003	1089	952
Excel 505	735	831	1052	1100	637	603	1092	1002
N.K. 222G	685	906	841	966	669	753	960	991
Dekalb F-64	839	920	1003	1129	796	720	1041	1004
NC-T-700	864	875	884	954	584	1077	1103	1070
Asgrow Flare	668	736	984	1172	676	949	1093	1080
N.K. 275	987	1002	870	1135	724	885	1172	1189
Horizon 80	830	895	858	1233	849	804	1146	1131
Dekalb E-57	1153	977	867	1077	830	824	1005	949
Asgrow Jumbo C	803	724	1162	907	1026	1100	755	382
Dekalb C-48a	909	1113	1021	1097	949	935	1395	1021
Advance 91	881	1030	928	834	739	810	1178	986
Dekalb C-44c	944	1111	1062	1023	899	1164	1092	903
Advance 76	799	867	807	1162	771	744	866	460
Acco R2020	955	822	858	868	655	767	1032	911
Acco R109	1062	1045	932	1090	700	729	877	1032

A-10. Mean data for kernel number for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing ( $10^2$ ).

Variety	Manhattan 1969		Ashland 1970		Pownhattan 1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	2153	2555	2058	2322	1627	1843	1775	1751
T. E. Mucho	1952	1618	1756	1556	1389	1639	2051	1993
W. M. G-61y	2299	2749	1958	1783	1690	1793	2055	2293
G. M. A.	2059	2074	1631	1713	1701	1410	2070	1993
W. M. 76y	1827	2147	2056	1825	1775	1746	1913	1899
RS 671	1382	2445	1913	1946	1556	1831	1925	2220
RS 702	2731	2366	2418	2326	1699	1666	2157	2275
RS 633	2491	1793	1828	1573	1393	1629	1645	1318
RS 626	1805	1983	1893	2155	1780	1942	1865	2204
RS 625	2138	1925	1629	1771	1557	1617	1659	1779
Richardson 404SR	2061	1869	1939	1669	1513	1787	1674	2254
P.U. 685	1615	2365	2155	1608	1686	1735	1755	1529
Pioneer 820	1980	2889	1462	1921	1637	1470	2139	2245
Pioneer 845	2411	2789	1596	1686	1363	1649	1945	2311
P.U. 634	2555	2510	1491	1941	1086	1548	2016	2425
Pioneer 846	2152	2338	1209	2068	1893	1325	2194	2072
Pioneer 828	2178	2022	1528	1823	1386	1444	1832	1761
N.K. 222A	1984	2230	1181	1364	1692	1356	2061	1799
Excel 707	2314	1691	2075	1934	1657	1793	1949	1823
Frontier 414	1734	1862	2008	1865	1384	1881	1815	2328
Frontier 413	1934	1250	1589	1389	1545	1532	1657	2110
Excel 505	1733	1840	1751	1671	1572	1923	1827	2145
N.K. 222G	1854	1780	1594	1859	1923	1523	1842	1581
Dekalb F-64	1560	1558	1986	2023	1658	1681	1967	1425
NC-T-700	1294	1714	1610	1789	1788	1550	1810	1758
Asgrow Flare	1361	2159	1893	2395	1488	1630	1911	1667
N.K. 275	894	2505	1884	1984	1606	2004	2197	1693
Horizon 80	2087	2252	1838	2102	1663	1805	1900	2008
Dekalb E-57	1364	1405	1999	2106	1529	1430	1818	1693
Asgrow Jumbo C	758	1070	2650	2246	1832	1473	488	802
Dekalb C-48a	1982	2284	1982	1580	2075	1604	1882	1169
Advance 91	1164	1867	1526	1899	1921	1785	1911	2152
Dekalb C-44c	2219	2555	1641	1672	1769	1700	1953	2078
Advance 76	1926	1381	1580	1651	1182	1654	1473	964
Acco R2020	1837	2185	1842	1245	1424	1652	1826	1822
Acco R109	1483	2859	2568	2036	1649	1472	1765	2106

A-11. Mean data for kernel weight for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing (10<sup>-2</sup>).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	2825	2769	2561	2884	2887	2665	2283	2313
T. E. Mucho	3133	3117	2720	2703	2626	2772	2478	2453
W. M. G-6ly	3546	3602	3177	3106	3472	3477	2411	2488
G. M. A.	3546	3342	2781	3141	2860	2864	2498	2275
W. M. 76y	2927	3133	2884	2887	3053	2927	2465	2513
RS 671	3378	3277	2498	2765	2870	3027	2341	2388
RS 702	3094	3149	2470	2183	2682	2607	2126	2142
RS 633	3222	3285	2651	2546	2564	2682	2580	2753
RS 626	3492	3698	2894	2714	2884	2806	2372	2341
RS 625	2897	3333	2744	2717	2392	2567	2422	2682
Richardson 404SR	3113	3041	2917	2966	2934	2796	2185	2291
P.U. 685	3201	3365	2604	2759	2803	2759	2376	2461
Pioneer 820	3137	3255	2884	3125	2962	2921	2277	1875
Pioneer 845	3157	3268	2904	2931	2674	2732	2493	2607
P.U. 634	3243	3676	2990	3067	3049	3034	2399	2490
Pioneer 846	3743	3298	2662	2756	3067	3034	2356	2376
Pioneer 828	3660	3577	3071	3197	3102	3045	2643	2037
N.K. 222A	3561	3876	3185	3067	2924	2857	2732	2654
Excel 707	3238	3185	2411	2556	2934	2599	2451	2441
Frontier 414	3053	2822	3041	3012	2952	2703	2418	2321
Frontier 413	2887	2948	2870	2841	2750	2703	2629	2508
Excel 505	3521	3060	2596	2671	3027	2822	2321	2444
N.K. 222G	3546	3497	3213	3106	2990	2812	2577	2634
Dekalb F-64	2976	3193	2867	2726	2818	2657	2453	2485
NC-T-700	2887	3034	2910	2851	2934	2674	2097	2306
Asgrow Flare	3311	3238	2610	2510	2525	2583	2350	2388
N.K. 275	3045	3053	2720	2685	2880	2803	2328	2475
Horizon 80	3173	2914	2612	2637	2665	2551	2404	2483
Dekalb E-57	3090	3238	2508	2332	3038	2844	2267	2456
Asgrow Jumbo C	2765	2626	2267	2051	2061	1917	1583	1687
Dekalb C-48a	3222	3034	2503	2637	2518	2406	2178	2415
Advance 91	3129	3298	2917	2834	2741	2607	2264	2273
Dekalb C-44c	3106	3034	2657	2691	2691	2694	2264	2615
Advance 76	3285	3472	2668	2588	2806	2809	2583	2432
Acco R2020	3060	3008	2966	3045	2914	2844	2449	2326
Acco R109	3458	3737	2931	2917	3383	3272	2444	2388

A-12. Mean data for kernel weight for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing (10<sup>-2</sup>).

Variety	Manhattan		Ashland		Pownhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	2703	2500	2822	2621	2851	2904	2485	2388
T. E. Mucho	2640	2674	2784	2815	3064	2874	2572	2430
W. M. G-6ly	2778	2790	3251	3067	3320	3463	2541	2515
G. M. A.	2525	2593	2831	2535	2914	3016	2441	2505
W. M. 76y	3090	2723	2818	2738	3012	3064	2456	2449
RS 671	2790	2374	2884	2860	2962	2973	2381	2323
RS 702	1956	2515	2778	2691	2599	2646	2199	2277
RS 633	2240	2753	2851	2778	2844	2897	2769	2621
RS 626	3234	2815	2697	2415	3023	2825	2336	2523
RS 625	2660	3053	2904	2874	2735	2735	2651	2596
Richardson 404SR	2076	2388	3053	2729	2803	2990	2306	2417
P. U. 685	2723	2388	2488	3045	2803	2844	2415	2244
Pioneer 820	2068	2385	3005	2860	3008	3117	2367	2451
Pioneer 845	2046	2277	3161	3090	2917	2870	2612	2591
P. U. 634	2508	2413	3094	2894	3083	3094	2621	2500
Pioneer 846	2425	2541	3008	2741	3169	3129	2500	2463
Pioneer 828	2408	3023	3117	2980	3079	3189	2441	2381
N. K. 222A	2668	3023	3411	3365	3222	3526	2601	2732
Excel 707	2395	2781	2847	2812	2800	2884	2374	2390
Frontier 414	2533	2061	2884	2706	2646	2800	2256	2341
Frontier 413	2073	2379	3027	2880	2593	2700	2495	2706
Excel 505	2561	2682	2857	2831	3049	2983	2385	2483
N. K. 222G	2548	2969	3222	3049	3109	3106	2451	2434
Dekalb F-64	2323	2790	2894	2998	2969	2927	2321	2385
NC-T-700	2959	2680	2998	2890	2864	2685	2473	2313
Asgrow Flare	2208	2677	2834	2580	2732	2775	2153	2352
N. K. 275	2962	2632	2688	2841	2815	2781	2475	2483
Horizon 80	2508	2945	2834	2640	2726	2806	2291	2461
Dekalb E-57	2987	2980	2756	2615	3226	3193	2374	2341
Asgrow Jumbo C	2585	2439	1956	2197	2183	2104	1671	1705
Dekalb C-648a	2543	1992	2803	2825	2662	2847	2381	2068
Advance 91	2784	2070	2747	2691	2769	2691	2226	2189
Dekalb C-444c	2191	2119	3049	2793	2907	2851	2418	2418
Advance 76	2593	2806	3027	2860	3086	3071	2478	2363
Acco R2020	2413	2006	2914	2877	2884	2796	2381	2383
Acco R109	3987	2520	3255	3157	3434	3687	2345	2415

A-13. Mean data for average of the 4th and 5th leaf area for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing (10<sup>-1</sup>).

Variety	Manhattan 1969		Ashland 1970		Powhattan			
	I	II	I	II	I	II	I	II
WAC 690A	4531	4540	5379	5876	4294	4205	5786	5955
T. E. Mucho	3668	3695	5075	5307	4126	3868	4507	4800
W. M. G-6ly	4876	5035	6199	6321	4473	4986	6372	6511
G. M. A.	4162	3808	4848	5471	3818	3937	4796	7093
W. M. 76y	4287	4453	6182	6369	4581	4217	6598	4915
RS 671	4360	4176	5377	5898	3833	3992	6261	6105
RS 702	4444	4553	6243	6390	4204	3914	6958	6658
RS 633	4124	4128	5803	5896	4304	3771	5638	5068
RS 626	3668	4009	5527	5838	3811	3961	6002	6033
RS 625	4110	4055	4877	5446	4174	3900	5382	4564
Richardson 404SR	4663	4178	6144	6452	4187	4332	6450	6903
P. U. 685	4313	4152	5731	6033	4253	3979	5964	5945
Pioneer 820	4330	4567	5675	6290	3941	4732	7345	6680
Pioneer 845	3862	3814	5471	5805	3593	4013	5680	6235
P. U. 634	4580	4697	5784	6336	4371	4524	5984	6698
Pioneer 846	4064	4434	6338	5916	4255	4124	5725	5824
Pioneer 828	3856	4147	6205	6436	4028	3779	6247	6575
N. K. 222A	4480	4508	5874	5991	4603	4412	7059	6364
Excel 707	4360	4550	5367	5371	4110	4074	5633	5552
Frontier 414	4804	4969	6491	6627	4177	4446	7059	7171
Frontier 413	4460	4555	5952	6173	4132	3924	6098	6429
Excel 505	3918	3977	4796	5358	4056	4201	5427	4954
N. K. 222G	4153	5315	5787	6366	4319	4483	6814	6982
Dekalb F-64	4563	4439	6152	6367	4464	4131	6266	7064
NC-T-700	4717	4745	6163	5966	4244	4282	7013	6607
Asgrow Flare	3926	3767	5466	5689	4005	3493	5136	5685
N. K. 275	4454	4635	6028	5963	3985	3961	5886	5990
Horizon 80	4342	4521	5947	5736	4268	4064	5789	5365
Dekalb E-57	4344	4476	5886	5832	4727	4412	6258	6558
Asgrow Jumbo C	5210	5020	7091	6647	2907	3042	7004	7136
Dekalb C-48a	4510	4901	6188	6760	5200	4192	8895	6565
Advance 91	4554	4498	5631	6045	4326	4038	5709	6998
Dekalb C-44c	4267	4449	5890	6197	4639	3923	7076	6121
Advance 76	4110	4560	5823	5953	4331	4306	5709	6063
Acco R2020	4640	4483	5810	6226	3767	3965	6667	7075
Acco R2020	4900	4900	5775	5871	4535	4989	6331	5863

A-14. Mean data for average of the 4th and 5th leaf area for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing ( $10^{-1}$ ).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	4757	4621	6014	5926	4720	4317	5767	6590
T. E. Mucho	4398	3956	5353	5117	4186	4338	4477	5334
W. M. G-61y	5914	5224	6656	6522	5200	5620	6606	7197
G. M. A.	4508	4276	5353	5474	4228	4117	4710	5659
W. M. 76y	5394	4807	6509	6777	4528	4631	7088	7479
RS 671	4810	4517	6206	6060	4339	4018	5943	6427
RS 702	4800	4717	6632	6656	4770	3957	7113	6489
RS 633	4243	4251	5816	6175	3936	4283	5273	6339
RS 626	4591	4035	5934	5514	4279	3998	5787	6102
RS 625	4507	4087	5595	5711	4185	4127	4400	4626
Richardson 404SR	5346	4821	6843	6766	4759	4554	6743	6477
P.U. 685	4729	4448	5916	6385	4465	4274	6126	6578
Pioneer 820	5085	5125	6332	6096	4525	3854	7481	7265
Pioneer 845	4201	4292	6030	5509	4063	3950	6108	6116
P.U. 634	4660	4336	6324	6155	4524	4627	6276	6218
Pioneer 846	4235	4409	6167	5410	3973	4357	6289	6811
Pioneer 828	4869	4908	6209	6449	4597	4542	7502	7552
N.K. 222A	4835	4540	6045	5452	5163	4940	6380	6265
Excel 707	5115	4719	5811	6422	4738	4208	5610	6091
Frontier 414	5430	5258	7095	7198	4920	4422	7661	6777
Frontier 413	5164	4659	6805	6643	4303	4115	6589	6404
Excel 505	4502	4218	5311	5494	3987	4401	5323	5809
N.K. 222G	5195	5143	6562	6541	4998	4717	7152	7410
Dekalb F-64	5268	5158	6628	7162	5096	5375	7025	7665
NC-T-700	5655	5464	6785	6443	5100	4489	6750	7020
Asgrow Flare	4696	3980	5276	5401	4734	4187	5503	5807
N.K. 275	4610	4611	6554	6192	4493	4999	6170	6549
Horizon 80	4926	4759	5838	6092	4217	4250	5952	5934
Dekalb E-57	5255	4649	5945	6157	4595	4442	6373	6896
Asgrow Jumbo C	4786	4893	7005	6987	3600	3475	8014	7628
Dekalb C-48a	5640	5080	7147	7160	5591	4331	6985	8009
Advance 91	5009	4888	6403	6680	5374	4545	6424	6675
Dekalb C-44c	5228	4698	5669	6648	4881	4201	6535	7410
Advance 76	4684	4394	6474	6476	4159	4026	6397	7180
Acco R2020	5212	5155	6657	6771	4484	4369	6527	7197
Acco R109	5671	5325	6837	6535	4804	4636	6209	6767

A-15. Mean data for head number for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 6 inch spacing ( $10^{-2}$ ).

Variety	Manhattan 1969		Ashland 1970		Powhattan			
	I	II	I	II	I	II	I	II
WAC 690A	110	100	150	110	110	100	135	140
T. E. Mucho	105	100	105	115	100	110	205	160
W. M. G-6ly	115	110	180	155	100	100	205	190
G. M. A.	105	100	110	130	105	105	170	190
W. M. 76y	105	105	140	110	115	105	155	110
RS 671	100	100	125	110	100	105	160	145
RS 702	110	115	175	130	105	100	165	215
RS 633	125	115	155	130	100	105	170	190
RS 626	110	100	110	135	100	100	150	155
RS 625	100	100	105	110	105	100	170	165
Richardson 404SR	100	100	120	110	100	100	160	180
P.U. 685	100	100	120	110	100	105	125	185
Pioneer 820	100	100	120	115	100	100	180	135
Pioneer 845	120	100	120	140	100	110	165	150
P.U. 634	100	115	115	115	100	105	230	140
Pioneer 846	100	110	130	115	105	100	155	135
Pioneer 828	100	100	110	105	100	110	200	145
N.K. 222A	100	100	120	105	105	100	165	115
Excel 707	100	100	115	125	100	100	160	160
Frontier 414	100	100	140	100	105	105	165	175
Frontier 413	100	100	105	125	100	100	170	145
Excel 505	100	105	125	110	100	100	160	175
N.K. 222G	100	100	145	140	100	105	150	190
Dekalb F-64	100	100	130	125	100	100	165	130
NC-T-700	105	100	100	115	105	100	140	150
Asgrow Flare	120	100	125	130	100	100	120	185
N.K. 275	100	105	105	105	100	100	145	165
Horizon 80	100	100	115	110	100	110	155	175
Dekalb E-57	100	100	120	115	100	100	130	185
Asgrow Jumbo C	100	100	130	145	100	100	165	225
Dekalb C-48a	100	100	120	110	100	100	190	175
Advance 91	105	100	120	125	100	105	170	175
Dekalb C-44c	100	100	130	130	105	100	165	145
Advance 76	100	100	110	125	100	105	135	140
Acco R2020	100	100	105	105	100	100	170	150
Acco R109	105	100	165	140	100	110	130	200

A-16. Mean data for head number for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 12 inch spacing ( $10^{-2}$ ).

Variety	Manhattan 1969		Ashland 1970		Powhattan			
	I	II	I	II	I	II	I	II
WAC 690A	145	200	170	230	140	100	265	210
T. E. Mucho	140	200	130	160	120	150	315	315
W. M. G-61y	175	300	180	245	180	200	300	420
G. M. A.	135	165	105	235	120	135	270	235
W. M. 76y	130	145	150	190	140	125	260	290
RS 671	175	230	145	180	130	115	260	310
RS 702	225	230	220	215	110	130	350	380
RS 633	175	215	230	245	135	135	300	260
RS 626	155	230	195	125	130	150	285	260
RS 625	135	230	195	120	145	150	360	300
Richardson 404SR	140	210	160	150	125	115	325	335
P.U. 685	195	195	170	150	175	115	315	230
Pioneer 820	165	230	125	155	155	125	335	325
Pioneer 845	135	235	150	165	115	135	325	315
P.U. 634	195	265	185	245	150	135	300	340
Pioneer 846	145	255	120	210	150	170	315	260
Pioneer 828	105	215	120	155	165	130	320	215
N.K. 222A	125	170	120	165	150	115	295	235
Excel 707	125	135	205	125	135	125	260	275
Frontier 414	120	115	135	130	145	120	295	275
Frontier 413	105	105	125	115	110	130	300	280
Excel 505	100	115	185	130	140	140	300	320
N.K. 222G	100	120	190	175	170	185	275	155
Dekalb F-64	105	120	160	175	125	100	355	255
NC-T-700	100	175	125	125	135	110	280	255
Asgrow Flare	190	275	175	235	165	175	350	295
N.K. 275	135	175	150	180	115	145	250	215
Horizon 80	125	155	180	215	120	130	295	300
Dekalb E-57	110	235	210	210	125	115	255	220
Asgrow Jumbo C	170	175	205	240	160	130	305	325
Dekalb C-48a	160	195	165	140	180	125	280	235
Advance 91	160	175	200	180	170	150	250	290
Dekalb C-44c	175	245	145	155	125	130	245	280
Advance 76	160	190	195	170	115	115	215	170
Acco R2020	120	150	120	115	145	125	240	275
Acco R109	185	265	230	260	135	110	350	410

A-17. Mean data for peduncle diameter for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 6 inch spacing ( $10^{-2}$ ).

Variety	Manhattan 1969		Ashland 1970		Powhattan			
	I	II	I	II	1969		1970	
WAC 690A	1122	1184	1052	1031	918	941	994	1056
T. E. Mucho	1091	1096	1100	1045	837	801	932	1050
W. M. G-61y	1034	1159	1016	1037	786	871	981	1022
G. M. A.	1083	945	1038	1059	878	841	974	1103
W. M. 76y	1072	1023	1109	1035	868	859	1005	963
RS 671	1144	1144	974	1062	838	893	1098	1079
RS 702	1068	1071	1041	1120	860	826	1068	1034
RS 633	950	993	941	980	776	800	992	893
RS 626	1109	1105	1137	1221	819	836	1080	1080
RS 625	1167	1073	1028	1086	814	836	981	905
Richardson 404SR	1071	1085	986	1047	819	834	1056	1079
P. U. 685	1064	1080	1092	1090	812	831	1069	1067
Pioneer 820	854	967	845	961	810	892	1043	1020
Pioneer 845	998	999	1020	993	827	876	994	1155
P. U. 634	1081	1040	814	924	759	803	954	1012
Pioneer 846	881	921	929	1019	786	754	942	948
Pioneer 828	919	992	1045	1066	810	797	966	1041
N. K. 222A	1029	1006	1023	1019	906	837	1043	1106
Excel 707	1064	1171	888	981	756	850	1011	1058
Frontier 414	1036	1126	1071	1146	833	944	1143	1136
Frontier 413	1029	1054	920	987	732	796	990	1119
Excel 505	1102	1057	979	977	782	821	982	941
N. K. 222G	995	1025	853	962	788	835	1048	1060
Dekalb F-64	1092	1036	897	930	827	821	1008	1132
NC-T-700	999	1144	1081	1067	812	881	1141	1128
Asgrow Flare	899	901	964	963	753	805	896	954
N. K. 275	1018	1072	1077	1054	766	816	1043	988
Horizon 80	1077	1166	1118	1138	827	949	1052	1043
Dekalb E-57	923	997	919	939	853	854	1026	1041
Asgrow Jumbo C	935	945	1009	1058	743	704	1202	1098
Dekalb C-48a	966	1030	1054	1152	879	803	1078	1157
Advance 91	1115	1027	1001	1031	808	853	1108	1156
Dekalb C-44c	967	991	1073	1158	794	815	1157	1021
Advance 76	943	1010	1044	1008	819	940	1086	1106
Acco R2020	1094	1045	998	1085	778	850	1061	1192
Acco R109	1109	1019	905	972	774	872	1035	1081

A-18. Mean data for peduncle diameter for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 12 inch spacing ( $10^{-2}$ ).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	1303	1230	1086	1104	1111	1040	1120	1205
T. E. Mucho	1188	1271	1034	1114	1121	1123	987	1105
W. M. G-6ly	1242	1148	1081	1102	1135	1095	1013	1097
G. M. A.	1210	1252	1136	1181	1048	1015	998	1133
W. M. 76y	1230	1259	1110	1067	1040	1118	1165	1277
RS 671	1207	1272	1119	1086	1037	1116	1051	1129
RS 702	1131	1147	1119	1122	1027	1036	1146	1062
RS 633	1005	1046	951	1038	949	1069	941	1077
RS 626	1230	1173	1125	1216	1048	1067	1093	1097
RS 625	1271	1188	1143	1129	1102	1064	983	972
Richardson 404SR	1154	1228	1155	1146	1062	1105	1065	1084
P.U. 685	1164	1230	1219	1134	1094	1128	1034	1149
Pioneer 820	1064	1139	1052	1083	979	947	1108	1009
Pioneer 845	1156	1103	1056	1073	1007	1073	1058	1116
P.U. 634	1020	1057	938	1001	1017	968	968	1013
Pioneer 846	1010	1067	1049	1054	935	966	1027	1079
Pioneer 828	1182	1250	1072	1184	1031	950	1129	1209
N.K. 222A	1205	1181	1135	1036	1124	1111	1097	1099
Excel 707	1250	1269	1029	1149	1070	1114	1135	1110
Frontier 414	1171	1238	1134	1268	1205	1117	1292	1102
Frontier 413	1168	1085	1129	1138	939	1044	1135	1033
Excel 505	1192	1230	1060	1098	1098	994	1088	967
N.K. 222G	1155	1176	993	1010	1043	1005	1092	1174
Dekalb F-64	1122	1240	1059	1071	1135	1187	1178	1223
NC-T-700	1197	1273	1089	1175	1325	1047	1150	1168
Asgrow Flare	1097	984	922	1025	982	946	945	1079
N.K. 275	1161	1194	1145	1113	1042	1140	1030	1103
Horizon 80	1227	1180	1099	1130	1071	1161	1081	1038
Dekalb E-57	1064	1106	980	1039	1110	990	1123	1169
Asgrow Jumbo C	1135	1128	1173	1272	938	952	1297	1381
Dekalb C-48a	1176	1153	1198	1191	1186	1060	1105	1148
Advance 91	1192	1202	1052	1088	1162	1095	1076	1170
Dekalb C-44c	1182	1126	1064	1143	1047	1010	1083	1152
Advance 76	1191	1164	1131	1176	926	1018	1174	1409
Acco R2020	1170	1290	1126	1221	1085	1044	1148	1181
Acco R109	1199	1127	1089	1053	1075	1019	1145	1120

A-19. Mean data for total stomata per plant (tip, middle, and base) for 36  $F_1$  hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing ( $10^2$ ).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	13446	12895	13716	12986	8211	9560	13398	15985
T. E. Mucho	8923	7822	12139	14048	10422	11082	9305	11785
W. M. G-6ly	12799	11395	16192	14032	9129	14561	13225	17042
G. M. A.	10897	12245	12432	11519	9368	7597	9637	17877
W. M. 76y	11243	12166	18858	19313	9927	8853	17152	12477
RS 671	13644	8257	13910	13047	10401	10079	15582	18334
RS 702	13925	13023	19041	16135	8810	9854	17540	17813
RS 633	10972	10105	14210	12559	8765	8690	11517	10548
RS 626	10844	11244	14044	14468	7892	8666	14086	14595
RS 625	9251	9961	10109	12436	7239	8673	11519	8979
Richardson 404SR	12045	11747	14528	16521	9521	9879	17977	15035
P.U. 685	13809	10553	14823	16413	9287	11882	14129	15592
Pioneer 820	11249	12599	12961	15818	9279	12223	23863	17901
Pioneer 845	10540	9949	12547	13818	9333	11201	15389	16840
P.U. 634	11757	10727	17247	17729	10617	8012	15539	17449
Pioneer 846	10829	12584	18100	13926	13097	10007	13434	14442
Pioneer 828	12276	11826	14633	16136	10591	8677	17048	19066
N.K. 222A	11401	9357	15293	13475	9843	6868	14963	15175
Excel 707	11912	10160	12041	11875	8493	10160	13231	15720
Frontier 414	12373	11492	16382	17890	7709	9451	15762	17313
Frontier 413	10384	11067	18189	14445	8488	9436	14718	17648
Excel 505	12153	9702	12814	11982	8800	8411	12442	11638
N.K. 222G	10795	9270	12970	17855	9840	10678	17787	17500
Dekalb F-64	11439	8417	15270	14353	10317	7337	15230	16861
NC-T-700	11454	13810	18965	15709	8827	10500	16478	17227
Asgrow Flare	9403	10235	14147	15527	9404	7909	11853	12939
N.K. 275	11985	10078	14925	12046	8930	10854	14101	16272
Horizon 80	11466	9647	12040	14357	9074	8273	14062	12542
Dekalb E-57	15653	9519	12644	10609	8303	9241	13021	15361
Asgrow Jumbo C	13512	13304	26190	23938	8044	9940	21416	19032
Dekalb C-48a	9498	9518	13647	14046	10948	7457	20189	15234
Advance 91	10372	13522	13320	17608	11257	9261	17578	16507
Dekalb C-44c	8719	7807	12840	16516	10144	8843	16140	15409
Advance 76	9278	11032	15027	16097	10650	10554	12650	15098
Acco R2020	12741	9410	13304	13226	8899	10307	15363	18302
Acco R109	9942	11092	14757	13995	10972	10783	11777	12237

A-20. Mean data for total stomata per plant (tip, middle, and base) for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing (10<sup>c</sup>).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	9719	11229	18399	18340	10115	10085	12388	16411
T. E. Mucho	10389	10885	14586	12513	9786	10271	9020	11363
W. M. G-6ly	12368	10940	17342	17663	11339	13572	14364	13758
G. M. A.	13427	10458	14380	13195	10837	10016	10865	12093
W. M. 76y	10013	9021	18741	19512	12635	10847	18208	19966
RS 671	10804	10885	17320	18062	12294	9610	14453	18457
RS 702	11552	11190	17762	23140	13775	9543	16601	18302
RS 633	10141	9407	12376	16671	10598	11150	13226	13629
RS 626	11737	9992	16750	15187	10828	10778	13269	13842
RS 625	10127	7545	15397	13367	10929	8396	8952	8961
Richardson 404SR	9801	11330	20007	16238	10781	9864	16810	19263
P.U. 685	10943	10194	14525	16512	10122	10678	14247	17084
Pioneer 820	13371	9461	22173	18365	9524	9914	20983	20331
Pioneer 845	9175	10939	16906	14342	10227	8441	15341	15573
P.U. 634	9826	9451	13824	15883	10129	13348	14861	15612
Pioneer 846	13213	12686	17746	15093	11683	11515	14278	16127
Pioneer 828	9485	8895	18185	19077	13740	11511	19218	18916
N.K. 222A	12090	9945	17113	15856	12027	12179	16213	15715
Excel 707	12879	9923	16300	14974	12262	10589	13268	14835
Frontier 414	13954	11188	18344	16853	10368	9920	18931	16408
Frontier 413	11808	10098	15801	16442	11038	10661	17397	17470
Excel 505	13571	9508	13001	11849	10326	13321	14326	14110
N.K. 222G	10832	14437	18361	17666	11512	12094	16935	18914
Dekalb F-64	10041	10046	20557	18309	11495	10740	16475	16109
NC-T-700	12227	14069	19186	16282	9407	10860	16550	15668
Asgrow Flare	10602	9641	13281	11882	13292	12586	12532	12561
N.K. 275	9526	11061	19467	17249	9606	11055	15564	15727
Horizon 80	9855	11003	16626	14390	9807	9959	15617	12898
Dekalb E-57	10192	8847	13759	15308	10385	10019	13301	13414
Asgrow Jumbo C	9514	14706	27170	24829	10819	9999	20612	21075
Dekalb C-48a	12182	11050	18347	16520	8382	8187	15452	18020
Advance 91	13981	11628	19479	19486	12863	11529	18777	17731
Dekalb C-44c	10713	9665	14424	15475	9905	7928	13761	14759
Advance 76	9914	9683	21250	16301	13136	10307	15065	17610
Acco R2020	10685	9577	18849	16308	9576	10904	16025	17932
Acco R109	11186	12537	17939	18687	11804	12452	12270	13164

A-21. Mean data for total stomata per plant (middle portion only) for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing (10<sup>3</sup>).

Variety	Manhattan 1969		Ashland 1970		Powhattan			
	I	II	I	II	I	II	I	II
WAC 690A	12567	11648	13475	12602	8396	9161	12702	15659
T. E. Mucho	8918	8766	12601	14244	9592	11049	8832	10177
W. M. G-61y	13266	12525	15159	14057	9527	13563	12238	17692
G. M. A.	11197	11365	12662	10387	8694	7515	10154	16296
W. M. 76y	11229	11737	19149	19506	9153	8641	15338	11275
RS 671	13272	10294	14028	14415	9656	10139	16176	17592
RS 702	13550	13256	17261	15348	8650	9220	18100	18790
RS 633	11929	11043	15467	12969	8477	8209	11650	9662
RS 626	12066	11437	14319	13645	8019	9025	12827	13650
RS 625	10266	10663	10188	12901	8378	8711	11359	8574
Richardson 404SR	12491	12668	14202	15923	9508	10783	17345	13904
P.U. 685	13094	11280	15153	15344	8919	11337	12313	14612
Pioneer 820	12597	13621	12586	15621	10126	11190	25746	18972
Pioneer 845	10347	11489	13328	15409	9787	9966	15986	17255
P.U. 634	11050	11396	17808	20590	9791	8009	15205	17157
Pioneer 846	11580	11187	19778	15393	12202	9916	14209	12942
Pioneer 828	12686	11712	13552	16347	9605	8569	15933	17575
N.K. 222A	10342	10535	16928	14578	9498	7991	12551	15411
Excel 707	12723	12016	11471	11527	8472	10419	12042	14915
Frontier 414	13181	11602	17267	18880	7867	8938	16558	16846
Frontier 413	12450	11053	15627	14714	8241	9018	15086	16635
Excel 505	12649	12077	13323	12658	8461	8436	11476	12125
N.K. 222G	12281	11228	12446	16804	9687	10378	15361	17107
Dekalb F-64	13281	10248	13544	13106	10458	7776	14614	14980
NC-T-700	12195	13376	18748	15685	8746	10752	16264	16615
Asgrow Flare	10626	9762	14579	17663	9592	8839	10555	12258
N.K. 275	12318	11254	14901	11919	8598	10501	12682	15968
Horizon 80	12171	11115	13142	12951	8690	8590	12270	12133
Dekalb E-57	10247	11176	13757	11494	9147	9275	12255	14881
Asgrow Jumbo C	13467	14738	23466	22282	8250	9359	22962	19626
Dekalb C-48a	8624	12394	13846	11586	10399	8111	19594	12715
Advance 91	11290	12967	15538	17779	10298	9399	16936	16947
Dekalb C-44c	9565	10224	13880	16911	10251	10247	15836	14995
Advance 76	10692	11247	14614	15121	10896	10476	12228	15285
Acco R2020	12433	9744	13233	14964	8816	10418	14713	16493
Acco R109	10956	13784	14091	13729	10276	10044	10838	12344

A-22. Mean data for total stomata per plant (middle portion only) for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing (10<sup>2</sup>).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	10555	11996	19537	16885	10600	10631	11955	15043
T. E. Mucho	11363	10266	15283	12883	9790	9513	9033	10673
W. M. G-6ly	12489	10896	17501	16676	10400	12768	15292	13460
G. M. A.	13184	10258	14857	12021	10838	10830	9321	11871
W. M. 76y	11975	9690	20897	17732	11957	11765	18948	20500
RS 671	10922	11400	16325	17669	11578	9714	14111	20185
RS 702	12259	11058	19290	23244	12428	10227	15887	16865
RS 633	9467	8713	14182	17737	10224	10584	11590	12714
RS 626	11306	9642	16545	16234	11562	11331	11318	14300
RS 625	10968	8065	15974	13566	10581	10459	8787	10141
Richardson 404SR	11168	11224	19456	16713	10518	11416	15293	19703
P.U. 685	11858	10699	15849	20355	11053	10937	14368	16892
Pioneer 820	13314	10852	18032	17049	10503	9701	21829	25848
Pioneer 845	9653	10837	15575	14064	9567	9154	15824	18843
P.U. 634	9535	8982	13960	14735	10884	12415	14836	16982
Pioneer 846	12136	12176	17080	15007	11449	12166	14356	18547
Pioneer 828	10127	10819	17483	19118	12962	11924	17733	19096
N.K. 222A	12356	11167	15243	15836	12090	13083	15144	18681
Excel 707	12087	9870	16311	14485	12347	10926	13320	12506
Frontier 414	13307	11144	17800	17154	10866	10228	16018	14671
Frontier 413	11615	10435	16640	18890	11516	10520	17808	17653
Excel 505	13104	9909	12111	12843	10158	11954	15226	13406
N.K. 222G	11492	11703	18795	17514	11606	11751	17147	17182
Dekalb F-64	9906	10566	21350	19080	11347	11192	15211	16174
NC-T-700	12385	13265	19144	14108	10546	11226	15695	15886
Asgrow Flare	10962	9305	12567	12050	13332	11788	12023	11091
N.K. 275	10029	10864	18370	13158	10251	11794	15800	16930
Horizon 80	10691	11019	16981	15328	11118	10451	13898	11880
Dekalb E-57	10272	8347	13363	16376	10214	10224	12578	12328
Asgrow Jumbo C	11040	12323	26628	27308	11275	10558	21572	22651
Dekalb C-48a	11835	10227	17541	15959	9908	9633	14551	16136
Advance 91	12335	11012	19854	23053	14009	12436	20972	17140
Dekalb C-44c	11535	10542	12928	13914	11237	8746	11900	14784
Advance 76	10195	9315	20207	15550	11952	9598	14436	16187
Acco R2020	11085	10961	17722	15751	10146	10434	16344	19320
Acco R109	11889	12354	17354	19011	12342	12364	12768	13768

A-23. Mean data for stomata per mm<sup>2</sup> (center portion only) for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 6 inch plant spacing (10<sup>-1</sup>).

Variety	Manhattan		Ashland		Powhattan			
	1969		1970		1969		1970	
	I	II	I	II	I	II	I	II
WAC 690A	1566	1511	1298	1115	1115	1270	1223	1395
T. E. Mucho	1181	1043	1391	1380	1508	1583	1177	1165
W. M. G-6ly	1329	1150	1277	1126	1153	1570	1079	1470
G. M. A.	1353	1666	1435	1046	1435	1112	1315	1206
W. M. 76y	1308	1366	1511	1487	1249	1160	1260	1257
RS 671	1501	967	1311	1201	1542	1391	1389	1493
RS 702	1418	1315	1280	1112	1139	1308	1389	1538
RS 633	1267	1163	1353	1170	1167	1332	1142	1068
RS 626	1401	1360	1408	1260	1174	1229	1171	1257
RS 625	1077	1184	1167	1277	1991	1246	1206	1142
Richardson 404SR	1335	1187	1150	1198	1322	1260	1372	1119
P.U. 685	1621	1249	1332	1291	1174	1576	1119	1297
Pioneer 820	1181	1218	1074	1194	1132	1298	1757	1487
Pioneer 845	1325	1191	1212	1298	1353	1525	1447	1412
P.U. 634	1384	1139	1587	1597	1342	1012	1320	1297
Pioneer 846	1225	1267	1580	1301	1539	1301	1338	1182
Pioneer 828	1528	1311	1040	1236	1366	1215	1343	1320
N.K. 222A	1329	1084	1501	1229	1222	905	1119	1372
Excel 707	1366	1157	1146	1095	1181	1397	1165	1464
Frontier 414	1291	1177	1308	1373	1070	1191	1206	1263
Frontier 413	1170	1246	1287	1146	1191	1325	1309	1297
Excel 505	1446	1232	1518	1291	1280	1091	1188	1470
N.K. 222G	1229	1053	1070	1263	1291	1284	1165	1263
Dekalb F-64	1229	960	1098	1009	1291	960	1234	1131
NC-T-700	1238	1466	1556	1308	1146	1370	1211	1303
Asgrow Flare	1146	1294	1415	1580	1201	1170	1171	1188
N.K. 275	1366	1136	1236	1033	1277	1514	1177	1418
Horizon 80	1301	1129	1157	1115	1236	1160	1171	1246
Dekalb E-57	1745	1015	1260	1077	960	1129	1119	1240
Asgrow Jumbo C	1198	1170	1525	1480	1370	1373	1619	1389
Dekalb C-48a	984	895	1187	895	1129	929	1217	1085
Advance 91	1136	1470	1366	1456	1218	1267	1372	1309
Dekalb C-44c	1009	854	1267	1456	1160	1174	1300	1412
Advance 76	1070	1115	1274	1270	1315	1270	1217	1389
Acco R2020	1394	1060	1122	1150	1291	1432	1177	1240
Acco R109	1046	1091	1291	1184	1363	1181	1016	1160

A-24. Mean data for stomata per mm<sup>2</sup> (center portion only) for 36 F<sub>1</sub> hybrids for 2 replications, 2 years, and 2 locations at 12 inch plant spacing (10<sup>-1</sup>).

Variety	Manhattan 1969		Ashland 1970		Powhattan			
	I	II	I	II	I	II	I	II
WAC 690A	1053	1194	1649	1484	1146	1198	1188	1286
T. E. Mucho	1184	1339	1535	1391	1205	1273	1160	1160
W. M. G-61y	1095	1132	1318	1318	1163	1229	1286	1039
G. M. A.	1493	1284	1525	1187	1335	1308	1171	1234
W. M. 76y	940	960	1638	1305	1446	1287	1407	1458
RS 671	1112	1208	1363	1480	1442	1205	1280	1740
RS 702	1122	1163	1356	1559	1504	1143	1114	1326
RS 633	1198	1174	1311	1473	1353	1363	1211	1223
RS 626	1311	1229	1456	1566	1318	1415	1102	1343
RS 625	1132	998	1604	1298	1353	1046	1229	1349
Richardson 404SR	926	1181	1411	1232	1218	1108	1200	1521
P.U. 685	1157	1129	1353	1594	1249	1308	1303	1493
Pioneer 820	1198	912	1339	1335	1012	1191	1470	1757
Pioneer 845	1050	1284	1263	1267	1318	1119	1378	1556
P.U. 634	1143	1201	1132	1194	1157	1428	1200	1401
Pioneer 846	1415	1311	1435	1401	1387	1280	1297	1464
Pioneer 828	1012	895	1344	1415	1487	1187	1206	1378
N.K. 222A	1174	1098	1280	1545	1287	1308	1246	1625
Excel 707	1298	1084	1501	1184	1384	1294	1280	1160
Frontier 414	1311	1064	1212	1139	1136	1187	1056	1183
Frontier 413	1194	1150	1170	1335	1394	1346	1430	1447
Excel 505	1511	1105	1253	1267	1342	1645	1607	1315
N.K. 222G	1053	1112	1387	1263	1222	1308	1217	1240
Dekalb F-64	1022	1036	1669	1287	1184	1060	1119	1234
NC-T-700	1129	1253	1373	1084	1019	1225	1211	1240
Asgrow Flare	1146	1236	1284	1150	1418	1428	1252	1154
N.K. 275	1108	1246	1456	1101	1105	1260	1407	1562
Horizon 80	1053	1253	1484	1274	1205	1270	1269	1097
Dekalb E-57	1005	1015	1215	1411	1108	1125	1131	1010
Asgrow Jumbo C	940	1366	1621	1718	1411	1311	1326	1481
Dekalb C-48a	1046	1139	1263	1167	785	929	1114	1148
Advance 91	1473	1239	1535	1700	1308	1291	1653	1407
Dekalb C-44c	1012	1039	1253	1150	1012	916	953	1160
Advance 76	1053	1091	1549	1160	1504	1249	1194	1263
Acco R2020	1046	929	1305	1132	1167	1267	1435	1475
Acco R109	1022	1157	1305	1466	1187	1273	999	1097

STOMATA NUMBER AND INTERRELATIONSHIPS AMONG AGRONOMIC  
TRAITS IN F<sub>1</sub> HYBRIDS OF GRAIN SORGHUM,  
SORGHUM BICOLOR, (L.) Moench

by

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B. S., Michigan State University, 1969

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To fully understand yield, a continual investigation and analysis of the genetic, physiologic, and developmental level will have to be undertaken. The interrelationships of yield components and other agronomic traits are of utmost importance to fully understand yield and to be able to make use of these characteristics in a program for high yielding capacity.

This investigation was designed to estimate the interrelationships of grain yield, kernel number, kernel weight, head number, leaf number, half bloom date, peduncle diameter, plant height, leaf area, and stomate number. With special emphasis on the relationships of grain yield and stomate numbers and on kernel number and kernel weight. Association values for these traits were computed by three methods: simple correlation coefficients for interrelationships, and multiple and standard partial regression analysis for determining the relationships and relative importance among yield components contributing to grain yield.

The experimental materials utilized in this study consisted of 36  $F_1$  hybrids of grain sorghum. These were planted at 2 locations, for 2 years, with 2 replications, and at 2 different plant spacings, 6 and 12 inches, respectively.

Grain yield exhibited significant positive correlations with kernel number both years and both plant spacings in both locations. Associations of grain yield with kernel weight, plant height, peduncle diameter, half bloom date, and leaf area were variable among plant spacings and locations. These differences could be due to genetic-environmental interactions. The correlation between stomate number and grain yield was very low and nonsignificant, indicating that there is no association or the design was not sensitive enough to detect a significant correlation.

Negative significant correlations were found between kernel number and kernel weight in 3 of the 4 investigations carried out in this experiment. The positive significant correlation at Powhattan in 1970 could have been caused by climatic conditions; temperature, subsoil moisture, specific dates of rainfall, all interacting with the developmental sequence of the sorghum hybrids.

Interrelationships among the agronomic traits were variable with correlations between half bloom date and leaf number, head number and grain yield, peduncle diameter and leaf number (negative), half bloom date and plant height, and leaf number and plant height being the most highly correlated, but not significantly in all cases.

$R^2$  values of grain yield, computed from multiple regression analysis with 9 other traits, kernel number, kernel weight, head number, leaf number, leaf area, half bloom date, peduncle diameter, plant height, and stomate numbers, were high. Kernel number and kernel weight contributed the most. Standard partial regression coefficients of kernel number and kernel weight were high and significant, with kernel number contributing nearly twice that of kernel weight in their relation to grain yield.